THE UNIVERSITY OF ALBERTA

AN ASSESSMENT OF THE DEEP PLOWING POTENTIAL OF SOLONETZIC SOILS IN THE LEDUC AREA, ALBERTA

by

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ABSTRACT

The physical and chemical nature of Solonetzic soils inhibits production of agriculture crops. Within the Province of Alberta these soils have a large areal extent of approximately five million hectares. Numerous different methods of amelioration of Solonetzic soils have been tried. This study was initiated to develop a set of criteria that would act as guidelines for the assessment of the suitability of Solonetzic soil landscapes for amelioration by deep plowing. These assessment guidelines were tested on soil units mapped in a study area near Leduc, Alberta. This area includes both Solonetzic and non-Solonetzic soils.

The soil units within the study area were characterized according to the physical, chemical and soil landscape properties outlined in the assessment guidelines. These properties included such physical characteristics as internal soil drainage and soil texture, chemical characteristics such as the calcium content in the C horizon and the Ca/Na ratio in the surface horizon and soil landscape characteristics such as the distribution of different soils within a landscape. The soil units were then given a none to slight, moderate, moderate to severe or severe degree of limitation to deep plowing based on these properties.

The results showed that all the soil units were assessed a moderate to severe or severe degree of limitation. This is due to the need to refine the chemical criteria used and the complexity of the soil landscape at this scale of mapping.

The criteria used to develop the guidelines were based on the work of various researchers, personal communication and field observations.

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INTRODUCTION

From the early Russian work to the more recent work in North America, the chemical and physical nature of Solonetzic soils has been shown to inhibit the production of agricultural crops. Solonetzic soils are typically higher in their sodium ion concentration than associated non-Solonetzic soils and the former may be saline. Solonetzic soils are also characterized by a subsurface horizon that is hard when dry and sticky when wet restricting the downward movement of roots, air and water.

Within the province of Alberta, there are approximately five million hectares of Solonetzic soils of which 1.8 million hectares occur in the Black, Dark Gray and Gray Wooded soil zones (Peters 1978). Within the Edmonton region, Solonetzic soil landscapes have an areal extent of approximately 362,000 hectares. With the ever increasing demand for land for urban development and the diminishing base of arable agricultural land, it is becoming necessary to improve the productive capacity of Solonetzic soils.

There have been numerous studies to determine the success of different amelioration practices. These have ranged from the physical disturbance of the profile through land levelling, vertical mulching, deep ripping and deep plowing to chemical amelioration through the use of commercial amendments, soil conditioners and organic and inorganic fertilizers (Cairns 1978).

In spite of all the work done by various agencies, the question remains as to which soil-landscapes may be best suited for deep plowing

and which may present serious limitations to this practice.

The objective of this project is to develop and test a guide to assess soil-landscape suitability for deep plowing through:

(1) the definition of soil-landscape characteristics considered as limitations to deep plowing;

(2) the incorporation of the characteristics into a soil mapping legend;

(3) the mapping of an area containing solonetzic soil landscapes; and

(4) the assessment of each map unit in terms of the degree and kind(s) of limitation(s) to deep plowing.

To accomplish this, the following assumptions and delimitations were made:

(1) although various deep tillage methods have been devised, consideration is given only to that using a wheel plow (top soil saving plow);

(2) the necessity of applying this technique is not stressed, just the possible soil landscape limitations to its use;

(3) that soil landscapes are not irrigated; and

(4) only salt affected soils are considered and not others which may have some similar physical characteristics.

The Study Area

Location

The study area encompasses a single township immediately south of Leduc and approximately 24 km south of Edmonton.

This area was selected because of

(1) its close proximity to the University of Alberta allowing for easy access to and from the study site;

(2) the availability of existing information regarding the general climate, geology, hydrology and soils of the area; and

(3) the presence of several deep plowing plots already in the area under the auspices of Alberta Agriculture.

Climate

The climate of the area is considered to be continental, characterized by relatively warm summers and cold winters with a mean summer temperature of 13^{o}C and a mean winter temperature of -9^{o}C (Bowser et al 1962). The mean annual precipitation for the area varies from 40-45 cm with an average annual snowfall of 125 cm (Bowser et al 1962). The study site is included in Agro-Climatic Zone I which represents an area receiving adequate precipitation for the growth of crops and having greater than 90 frost-free days annually (Bowser 1967).

Geology

The bedrock geology of the area is related to the presence of poorly consolidated Upper Cretaceous bedrock of the Edmonton Formation

(Westgate 1969). This formation is a brackish water formation composed of interbedded bentonitic shales and sandstones, clays and coal seams.

Variable thicknesses of transported material over bedrock characterize the study area, with deep tills occurring in the northern section and residual bedrock in the south-central section. The Gwynne Outlet characterized by fluvial sand overlying till with minor gravel inclusions (Westgate 1969) cuts through the northeast corner of the study site. Glacio-lacustrine deposits of Lake Edmonton origin dominate the central portion of the study area.

Hydrology

The presence of two distinct groundwater flow regimes has been recognized in the Edmonton region flowing in a north to northwesterly direction towards the North Saskatchewan River which acts as a sink line (Moell 1977, Ceroici 1978). The first flow occurs within surficial deposits where the major ions tend to be calcium-magnesium bicarbonates. The second groundwater flow, dominated by sodium bicarbonates, occurs within bedrock material.

Soils

The study site was included within the area mapped during the reconnaissance soil survey of the Edmonton Sheet (83-H) (Bowser <u>et al</u> 1962).

The mode of deposition of materials within the site is variable. Parent materials include till, lacustrine and glacio-lacustrine deposits, fluvial deposits, colluvial deposits, residual bedrock material, fluvial deposits overlying till and till overlying residual bedrock material of various thicknesses which were deposited on top of the Edmonton Formation. In those locations where the Edmonton Formation is exposed (referred to as scabland; Westgate 1969), the parent material is residual bedrock. As a result soils formed on this material tend to be higher in sodium salts than adjacent soils and are classified as Solonetzic soils. Till and glacio-lacustrine deposits account for the majority of the parent materials within the area. The till deposits occur predominantly along the northern and western boundaries of the study site forming a semi-circle around the central portion of the study site. Glacio-lacustrine material occurs in the central portion. The remaining parent materials occur randomly throughout the remainder of the study site.

The topography of the land generally changes with a change in surficial material. Undulating to hummocky ground moraines are associated with till deposits, whereas a level to undulating surface expression is commonly found in areas of glacio-lacustrine deposits or residual bedrock. Recent fluvial material is found in drainage ways in fields.

The majority of the area is classified as 4D according to the Canada Land Inventory, Soil Capability for Agriculture (83-H), (Environment Canada 1967). The major limitation is undesirable soil structure and the areal extent of land classified as 4D corresponds well to what had been mapped in the reconnaissance soil survey as soils of the

Solonetzic Order. The remainder of the study site is classified as either Class 1, 2T or 3T. The areal extent of these classes corresponds to areas mapped with soils belonging to the Chernozemic Order.

Land Use

The land use patterns generally change as the soil orders change. Soils of the Gleysolic Order are usually left as pasture land whereas soils of the Chernozemic Order are used for cereal and forage crop production. Solonetzic soils are used primarily for pasture but where there is a greater depth of A horizon, such as with Solods, they are used for cereal crop production.

LITERATURE REVIEW

Genesis of Solonetzic Soils

Soil development is a function of topography, biota, parent geological material and climate in varying intensity over a period of time (Jenny 1941).

Gedroits, in his classical work in the early 1900's on soils that according to the Canadian System of Soil Classification (Canada Soil Survey Committee 1978) would be classified as Solonetzic, stated that the genesis of Solonetzic soils is a three-stage process. The stages being salinization, desalinization and solodization (Joffe 1936).

Salinization leads to a concentration of soluble salts, high in sodium, in the soil profile through groundwater discharge, capillary rise or evaporation.

Desalinization occurs as a result of soil leaching of soluble bases by precipitation or by the lowering of the groundwater table. The saturation of soil colloids with sodium results in their dispersion and the formation of a hard Bn(t) horizon characteristic of soils of the Solonetzic Order.

In the process of solodization, "calcium pumping" by plant roots in the upper A horizon places calcium from the parent material onto the exchange complex where it replaces the sodium cation. At the same time, sodium humates formed from the breakdown of organic matter by sodium and the sodium saturated clays disperse and are leached down cleavage planes. Lodgement occurs and the peds become stained.

As the processes of desalinization and solodization continue, soluble salts are being moved down the profile. Edaphic vegetation begins to dominate the site increasing the intensity of "calcium pumping" and humification of the A horizon. With the continuation of the processes of "calcium pumping", humification, desalinization and solodization, the Bn(t) horizon mellows and a Solod begins to form. With the prolongation of these processes the soils begin to acquire the characteristics of the zonally normal soils.

If the salts resulting from salinization are predominantly calcium or if through the process of leaching over ninety percent of the remaining exchangeable cations are calcium, then the saline soils are converted into a zonally normal soil and no Solonetzic soils would develop (Russell 1961). The above stress the importance of both the calcium contents and fluctuations in groundwater levels in the amelioration of Solonetzic B horizons or in the prevention of their formation.

Groundwater Flow and Solonetzic Soil Development

The relationship of groundwater fluctuations to the genesis of Solonetzic soils have been discussed by numerous authors.

In those instances where the water table is sufficiently close to the soil surface to prevent the leaching of the soil by surface water, no Solonetzic soils should develop even though the formation of Solonetzic soils requires the rise of sodium salt solutions to the surface (Glinka 1926). He also points out the effect of aspect on soil formation and groundwater movement by stating that Solonetzic soils may show a

preference for slopes where soils warm up faster with the consequent increase in evaporation and rise of sodium salts to the soil surface. Other studies by European and North American researchers have also shown the importance of groundwater movement in the development of Solonetzic soils. Muratova (1958) in the U.S.S.R. and Szabolcs (1965) in Hungary have both stated that salinization is a result of or associated with mineralized groundwater near the soil surface. Arshad and Pawluk (1966) found that Solonetzic soils formed from glacial lake sediments, such as those found within the study site, were found in relatively level groundwater discharge areas where capillary rise from the water table was a factor. In a study at Vegreville (Cairns 1977) piezometers were placed on a very thin Black Solonetz, a Black Solonetz and an Eluviated Black Chernozem. He found that there was a large variability in water table depths and sodium ion concentration. The results he obtained did not appear to be related to fluctuations in seasons, local climates or local relief.

Solonetzic Soil Development in a Landscape

Researchers have tried to relate the topographic position of a soil to the groundwater flow pattern. Menon (1971) in his work found that variations in slope can cause changes in soil characteristics. Such changes are often due to variations in the internal and external soil drainage regime.

Pawluk *et al* (1969) stated that in the Edmonton area, Orthic Black and Solonetzic Black soils occur in recharge and midline positions; Black Solods and Black Solonetz occur in discharge areas in the lower portion

of the midline position or the highest parts of the discharge areas; and saline Black Solonetz occur in groundwater discharge areas (Figure 1). These findings are substantiated by Leskiw's work (1971) in the Vegreville area where he found similar soil-topography relationships. Findings of Ellis et al (1970) show that in areas of Solonetzic soil the upper slope positions were occupied by Solonetz, the midslope positions where leaching was significant, by Solodozed Solonetz and the lower wetter slope positions occuppied by Solods (Figure 1). This sequence occurred over a wide range of parent materials. They also state that the position of solonetzic soils in a landscape is erratic.

Joffe (1936) describes a typical soil sequence as going from a zonally normal soil in the upper slope positions through a Solonetzic to Solodized Solonetz in the midslope position to a Solod in the lower slope position where leaching by water was the cause of solodization (Figure 1). These observations were confirmed by Bentley and Rost (1946) who also found the reverse soil sequence. They, too, found the upper slope positions occupied by the zonally normal soil. However, the midslope positions were occupied by solods which evolved to solodized solonetz then solonetz as the moisture regime downslope became wetter (Figure 1). They explain this by saying, "However, it appears that in such instances there is a locally higher water table which inhibits leaching in the lowest topographic positions. The solodized solonetz and solod profiles therefore develop in higher topographic positions where there is a more actual leaching." Generally speaking, research on soil development in a particular soil landscape points out that the recharge areas are occupied by the better drained soils, such as the zonally normal soils, the mid-

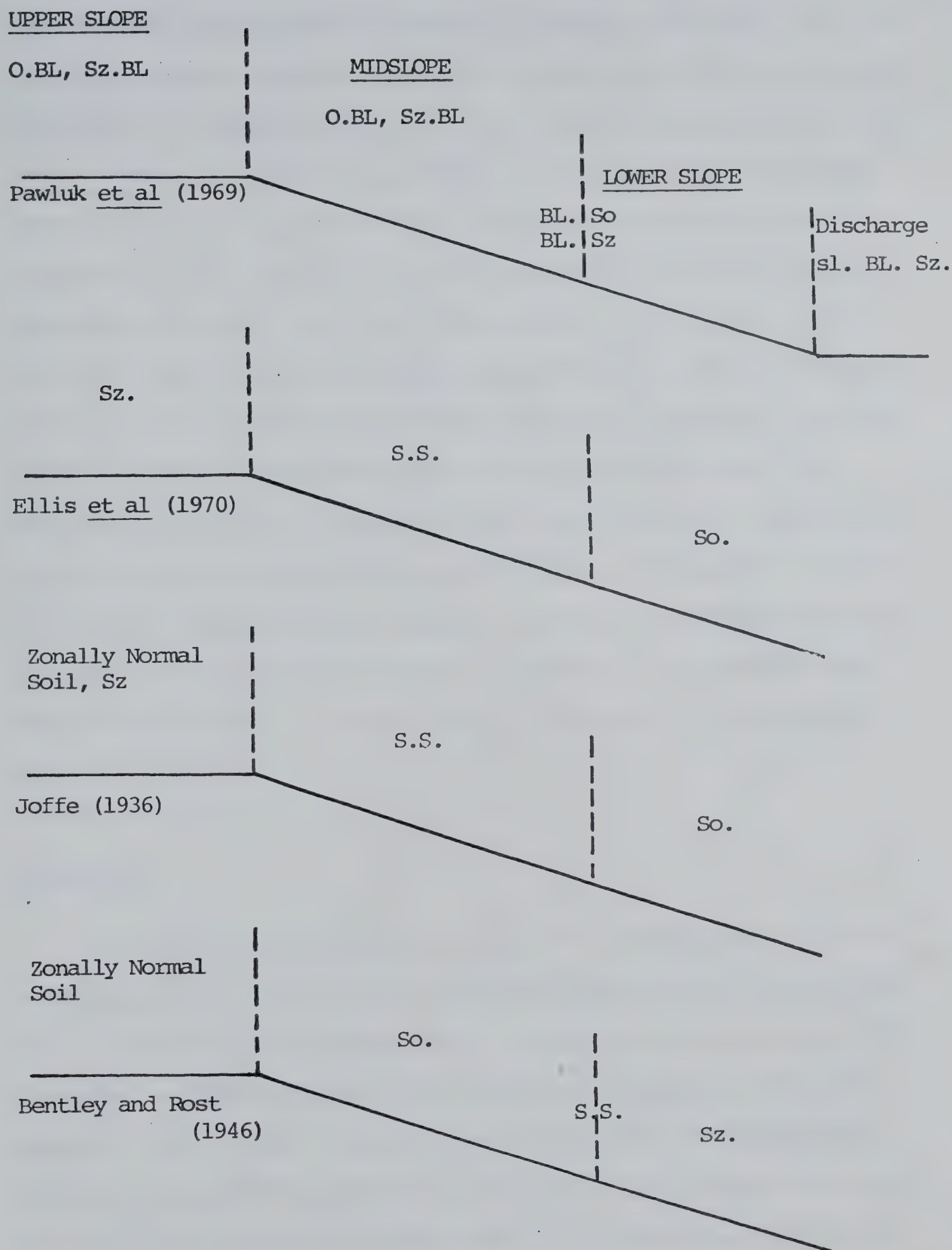


FIGURE 1 : Schematic Comparison of Solonetzic Soil Landscapes as Described by Various Authors

line positions are occupied by gleyed or slightly saline soils, and the discharge areas are characterized by soils developed under poorer drained conditions. If the ground water is high in sodium, a Solonetzic soil may develop (Menon 1971, Pawluk et al 1969). As the previous information indicates, by knowing something about the topography and the nature of groundwater flow, it should be possible then to predict where in a soil landscape a Solonetzic soil would likely occur. On the whole then in Solonetzic soil landscapes the upper slope positions should be occupied by Solonetz, the midslope positions by Solodized Solonetz and the lower slopes by Solods. In a Chernozemic-Solonetzic soil landscape, the Chernozemic soils should occupy the upper slope positions progressing to Solonetz then Solodized Solonetz in the midslope position and to Solods in the lower slope positions. However, it should be remembered that the one point that is indicated by most of the studies on Solonetzic soils is the great variability in the position of these soils in a topographic sequence.

Reclamation

The reclamation of Solonetzic soils can be broken down into two basic approaches. The first is a physical approach where the soil profile is disrupted by some means mixing the calcium rich C horizon with the sodium enriched B horizon. This has been attempted by either deep plowing or deep ripping. Deep plowing ideally involves the physical mixing of the B and C horizons only, with the A horizon placed back on top. The early single bottom plows mixed all three mineral horizons to a maximum depth of 90 cm with the result that the subsurface horizons were often at the soil surface making for a poor seedbed. With the

advent of the wheel plow the B and C horizons can now be mixed to a maximum depth of 60 cm and the A horizon placed back on top allowing for a more suitable seedbed. This is accomplished by the use of a grader blade which removes the surface horizon and deposits it on a rotating wheel which in turn deposits it back on top of the previously-plowed furrow. At the same time that the surface horizon is being removed, a plow is mixing the B and C horizons which will have topsoil placed on them from the next furrow. This results in a more suitable soil environment for seedling growth. The other method of physical disruption is through deep ripping. This involves "shattering" of the soil profile by a large chisel type plow called a "Texas Ripper." The drawback of this approach is that there is very little actual mixing of the subsurface horizons and these soils have a tendancy to retain their solonetzic nature.

The second approach is the chemical approach. This is usually accomplished through the addition of manure, commercial fertilizers or gypsum to the soil in an attempt to artificially speed up the processes of desalination and solidization.

Characteristics Important to the Reclamation of Solonetzic Soils

Most of the research being conducted at present on deep plowing deals with soils belonging to the Solonetzic order. Morphologically, this soil order is characterized by a solonetzic B horizon. This horizon often has distinct round tops and a very hard consistency when dry. Hence, the term hardpan is often applied to this horizons. As well, the B horizon may show sodium humate staining on the peds and compressed

roots along cleavage planes. When wet, the B horizon exhibits a sticky consistency. Solonetzic soils possess saline C horizons and originate from a parent material that was infused with salts then subjected to leaching by precipitation or lowering the water table.

Chemically, the most widely accepted general description of a Solonetzic soil is that of one having an acidic A horizon and an alkaline B horizon. It is generally agreed that the sodium content is responsible for the compact B horizon, poor structure, and poor water regime (Szabolcs 1971). The pH of the B horizon is usually ≥ 7 due to the higher than normal exchangeable sodium percentage.

Recently, attempts have been made to outline possible criteria that could be used to assess the suitability of soils for deep plowing.

A high calcium content in the C horizon is desirable so that when the B and C horizons are mixed there is sufficient calcium from the C horizon present to replace the sodium in the B horizon. The actual minimum amount of calcium considered necessary ranges from 20 meq/ℓ (Hermans 1980) and 25 meq/ℓ (Sandoval 1979) in the C horizon. Work done in North Dakota on Natriborolls supports this where soils that had a greater amount of soluble gypsum within the plow depth gave a better response to deep plowing than those low in soluble gypsum (Sandoval 1979).

Cairns and Hermans (1978) made several statements about soil conditions that led to a favorable response from deep plowing. They stated that soils with a definite hardpan but low sodium level in the Bnt horizon and high ratios of Ca^{+2}/Na^{+} in the lime salt layer below the Bnt horizon, showed a favorable initial response. They were classified as

Solods. These soils tended to have an acidic A horizon and benefited from the liming effect of deep plowing. A soluble Ca^{+2}/Na^{+} (saturated paste) or exchangeable ratio of ≥ 4 has been suggested as being necessary for good seedbed germination (Cairns 1978). Hermans (1980) in his work with a wheel move plow states that a soil with a pH of ≤ 6 should benefit from the liming effect of deep plowing, a situation that other researchers have mentioned also (Kurganskiiys and Yakovlev's 1937, Szabolcs 1971). Finally, the soil composition of the field to be deep plowed was mentioned as being a consideration with fields having a higher percentage of Solonetz and Solodized Solonetz not showing as favorable a response as those fields with lower percentages of these soils. This points out an area where research is lacking; would deep plowing be beneficial on non-Solonetzic soils?

Kjearsgaard (1980) outlined some of the possible criteria that should be considered before deep plowing (Table 1). These include classification at the order level, soil texture, surface drainage, parent material, topography and stoniness. He also discussed the necessity of having a "lime salt layer" within plow depth. For example, based on the average depth to the lime and salt horizon taken from soil survey information, Solonetzic soils of the Camrose series should not be deep plowed as the "lime salt layer" cannot be reached within the normal plow depth. Hermans (1980) concluded that at least 15 cm of gypsiferous C horizon must be within the usual maximum depth of deep plowing for the operation to be successful.

TABLE 1: Characteristics Important to Deep Plowing (after Kjearsgaard 1980)

Characteristic	Can Be Plowed	Should Not Be Plowed
Kind of soil (classification)	Solonetzic	Chernozemic, Regosolic, Gleysolic. Areas with >50% non Solonetzic soils.
Texture	loam, clay loam	Sandy loams and coarser, areas with >40% coarse soils.
Surface Drainage	well drained	poorly drained ground water discharge areas
Parent Material	till, fluv-lac, lacustrine	Soft rock (bedrock), aeolian, fluvial, areas with >30% soft rock.
Topography	<10% slopes	>10% slopes
Stones	<3% covered by by stones (S2)	>3% covered by stones (S3)

Development of a Technical Classification System

"The objectives of soil surveys are to provide reliable information on which to base some sort of land management or land treatment program that is in balance with and in close harmony with the physical nature of an area and still give an accurate geographic expression of the physical characteristics of an area" (Bartelli 1978). Technical classification then is a grouping of things together that are similar based on arbitrarily chosen criteria that are deemed important to the use of a group of soils for a particular purpose. All properties must be regarded as of equal importance. Therefore if a grouping of soils, such as a map unit, meet all the requirements for a slight limitation for a particular use, except one, then that one characteristic dictates that grouping of soils' final rating. As new knowledge is acquired, the technical classification will change and so may the rating of a particular group of soils.

Orvedal and Edwards (1978) define a technical classification as "the placing of soils for immediately practical objectives--objectives that pertain to the use and management of soils." Many of the properties that influence a soil's use in construction, engineering or as a base for plant growth are related to soils as natural bodies (Orvedal 1978). It is this relationship that allows one to take natural soil bodies and group them into classes of soils which behave alike regarding a specific use.

Summary

For the development of a realistic set of guidelines for assessing a soil's suitability for a favorable response to deep plowing, it is important to know the nature of the soil. From the models of genesis and empirical observations of different authors presented, certain characteristics should be evaluated before a soil or group of soils is judged as to its suitability for deep plowing. These characteristics include morphological and chemical characteristics such as those mentioned by Kjearsgaard (1980) and Cairns and Hermans (1978) as well as landscape features such as those mentioned by Kjearsgaard (1980) and Glinka (1926).

MATERIALS AND METHODS

Development of the Mapping Legend

In the development of the mapping legend particular attention was given to those soil/landscape characteristics considered important to the success of deep plowing using a wheel-move plow. It should be realized that many of these characteristics (depth to C horizon, etc.) could vary over short lateral distances. As a result a certain amount of variability occurs within a particular area or map unit.

Based on a reconnaissance soil survey (Bowser et al 1962) which encompassed the study site, geological reports and a prior knowledge of the general area, a number of different "soilscape groups" were established. A soilscape group as used by Coen (1977) is defined as "a defined and named aggregate of soil bodies grouped together on the basis of similar parent materials, drainage, soil and profile development."

The following soilscape groups were described as occurring within the study site:

Soilscape Group A -- Orthic Dark Gray Chernozems developed on till;

Soilscape Group B -- Eluviated Black and Orthic Black Chernozems developed on till;

Soilscape Group C -- Eluviated Black and Orthic Black Chernozems developed on glacio-lacustrine material;

Soilscape Group D -- Solonetzic soils developed on till;

Soilscape Group E -- Solonetzic soils developed on glacio-lacustrine material;

Soilscape Group F -- Solonetzic soils developed on residual bedrock material;

Soilscape Group G -- Gleysolic soils developed on fluvial, lacustrine and glacio-lacustrine material; and

Soilscape Group H -- Organic soils.

Appendix 1 gives a detailed profile description of each of the major kinds of soils found within the study site.

Each soilscape group was initially divided into various possible conceptual "soil units." Soil units (or soil mapping units) are defined as representations of a soil map of a part of the landscape having characteristics that fall into a range of limits described for that particular unit (Valentine et al 1979). The soil units describe a central concept of a soil landscape. Initial field checking resulted in the deletion of some of the original concepts, which were found not to exist within the study area, and the broadening of the scope of other units which were found to be too narrowly defined. The soil units used in this study were structured similarily to map units described in "A Proposed Soil Mapping System for Canada" (Valentine et al 1979). That is, each unit was divided into a dominant, significant and minor component based on the percentage of a particular soil(s) within a unit. The following separations were made: for a soil or soils to comprise the dominant component of a soil it had to occupy greater than 60% of that unit; for the significant component, 20 to 40% of the unit; and the minor component, less than 20% of that particular unit.

Each soil unit described within a particular soilscape group was given the designation of that group plus a numeric modifier. For example

the soil units within Soilscape Group "A" were designated as soil unit A1 and A2, for Soilscape Group "B", the units went from B1 to B7. Complete descriptions of the soil units are included in the section on Results and Discussion.

Field Mapping

In the spring of 1978, letters were sent to the landowners in the study site explaining the project and requesting permission to enter onto their land. In all instances permission was granted. During the 1978 and 1979 field seasons, soil investigations were conducted at the study site. Over the course of the study, 1421 point descriptions were made. Soil properties and surface features that could be readily described in the field were recorded on daily field sheets. Particular attention was paid to characteristics considered as possible limitations to deep plowing, such as the internal drainage regime of the soil and depth to C horizon. Numerous other sites were investigated to act as checks for verification as to the proper placement of a soil into a particular soil unit component. At each of the sites the morphological characteristics were described according to the "Manual for Describing Soils in the Field" compiled by Dumanski et al (1975).

After each site was described in the field, it was marked on an aerial photograph on which preliminary boundary lines had been drawn in the previous winter. The aerial photographs used were 2X enlargements of black and white panchromatic photographs at an original scale of 1:31680. The photographs were obtained from the Air Photo Branch of Alberta Energy and Natural Resources.

At the end of each field season, the preliminary soil boundary lines were finalized based on in-field investigations and aerial photo interpretation. The finalized soil boundary lines represented separations in the field based on changes in the kinds of soils in response to differences in topography, surface drainage and vegetation.

When all the soil boundary lines for the two years were finalized on the aerial photographs, they were transferred to the final 1:15840 base map.

Sampling and Analysis

At the conclusion of each field season, soil individuals most closely representing the central concept of the dominant and significant soils in the study area were described and sampled by horizon. Variants from the central concepts were also described and sampled. As well, for each pedon description landscape data were recorded. Three transects (Figure 2) representating a cross-section of parent materials in the study area were sampled to characterize soil toposequences.

A number of deep plowing plots within the study site were sampled (Appendix 3) at 15 cm depths or if horizons were recognizable, they were sampled.

This procedure of sampling the dominant and significant soils, along with selected variants, allowed for the acquisition of representative soil data of the study site without having to sample every individual soil unit.

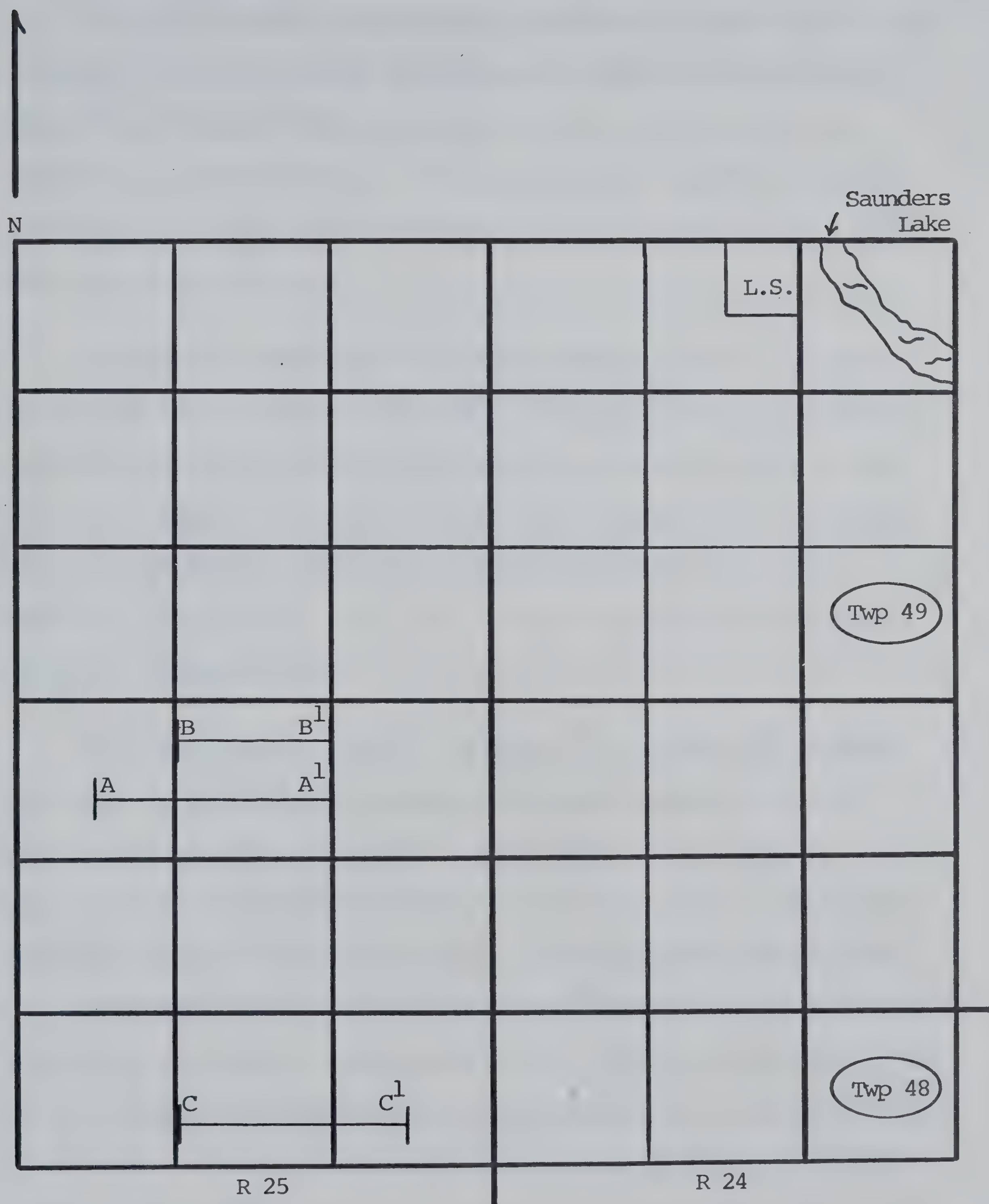


FIGURE 2 : Location of transects described in Appendix 2 and Figure 29.

The Soils Branch, Plant Industry Division of Alberta Agriculture, because of their own studies on deep plowing and their desire for the data, allowed samples taken during the course of this study to be analyzed along with their own. Similar analysis, therefore, was conducted on both sets of samples allowing for correlation of their data with that of the study site.

All samples taken were air dried, ground to pass a 2 mm sieve, and divided into two sets of samples. One set was sent to the Alberta Soil and Feed Testing Laboratory in Edmonton, while the other set was sent to the Alberta Environment Laboratory in Lethbridge. The Alberta Soil and Feed Testing Laboratory analyzed the samples for their electrical conductivity (E.C. x 10^3 mmhos) using standard laboratory procedures (McKeague 1976).

The second set of samples was sent to the Alberta Environment Laboratory in Lethbridge for analysis of water soluble calcium and sodium using the saturated paste extract method (McKeague 1976). Other analysis included percent saturation of the soil, soil pH (using a 2:1 distilled water to soil ratio) and the sodium adsorption ratio, again using laboratory techniques as outlined by McKeague (1976). The determination of the soluble salt content of the soil (including calcium and sodium contents) by the saturation extract method is the preferred method as it gives a better approximation in most cases of these cations in a natural soil solution than does a wider water to soil ratio (Ballantyne 1976). This method is useful in the determination of the gypsum ($CaSO_4 \cdot 2H_2O$) content of the soil as gypsum is more readily water soluble than

calcium carbonate (Hermans 1980). As pointed out earlier, the gypsum content of the soil is important (Sandoval 1979) to the success of deep plowing.

Development of Assessment Guidelines

Prior to the development of the assessment guidelines, several assumptions had to be made. They are as follows:

(a) cultivation would be done with a wheel-move plow (topsoil saving plow) with a cultivation depth of 60 cm,

(b) cultivation would take place on non-irrigated landscapes,

(c) that deep plowing is an amelioration practice for salt affected soils, and

(d) that these guidelines do not stress the necessity to deep plow rather only the possible soil and landscape limitations of it.

The guidelines have been divided into two basic areas of limitations to deep plowing. The first section deals with the potential physical and chemical soil limitations while the second section deals with the potential landscape limitations to deep plowing (Table 2). Each limitation was rated as having either a none-to-slight (N/S), moderate (M), moderate to severe (M/S), or severe (S) limitation to the success of deep plowing. This approach to assessing soil is the one outlined by Bartelli (1978) and has been used by both Coen (1977) and Greenlee (1980).

The criteria used to develop these guidelines are an amalgamation of what has been published by Cairns, Hermans, Sandoval and Kjearsgaard,

TABLE 2 : Soil and Landscape Limitations for Suitability of Solonetzic Soils for Deep Plowing

Soil Limitations

Properties Affecting Use		Degree of Limitation: None to Slight	Moderate	Moderate to Severe	Severe
1[1]	Slope Classes [2]	1,2,3 (0-5%)	4 (6-9%)		5,6,7,8,9,10 (>10%)
2	Slope Length	>12 m			<12 m
3	Surface Stoniness[2]	0,1	2		3,4,5
4	Soil Drainage[2]	Very rapidly, rapidly, well and moderately well drained	Imperfectly drained		Poorly, very poorly drained
5	Soil Texture (dominant to a depth of 60 cm)[2]	SL, FSL, VFSL, L, SiL, SCL, LS	SiCL, CL, Si, SiC, SC		C, Peat, muck, gravel, sand
6	Thickness of C horizon within 60 cm. plow depth	> 15 cm		<15 cm	
7	Parent Material	Till, glacio-lacustrine lacustrine, fluvial			Residual bedrock
8	Ca(meq/ℓ) in the C horizon	>20		<20	
9	Ca/Na ratio in surface horizon	>4:1		<4:1	
10	pH of surface horizon	≤ 6	>6		
11	Soil Landscapes	Solonetzic Chernozems and Solod, Solod and Solodized Solonetz, Solod and Solonetzic Chernozems, Solonetz, Solodized Solonetz and Solod, Chernozems, Solodized Solonetz and Solods, and Solonetzic Chernozems and Chernozems	Solonetz and Solod, Solodized Solonetz and Solonetz		Alkaline Solonetz, Gleysols

1 Corresponds to the numbers in the following section on "Rationale for Criteria in Table 2)."

2 These classes are defined in The Canadian System of Soil Classification (Canada Soil Survey Committee, 1978).

personal communication and field observation and are therefore conceptual in nature.

Rationale for Criteria in Table 2

1. Kjearsgaard (1980) states that any slope greater than 10% should not be deep plowed. This in the authors' opinion would constitute a severe limitation. Any slope greater than 10% should not be deep plowed due to the reduced efficiency of equipment and special post plowing management problems such as soil erosion. A slope of between 0 and 5% should offer no limitations to the normal use of equipment.
2. Assuming that the total length of the tractor and the wheel-move plow is 12 m, slopes should be at least this length to allow for proper depth control. This is especially important in those areas where there is just sufficient amounts of C horizon material present within normal plow depth. Any slopes less than 12 m in length could pose severe limitations to deep plowing.
3. Surface stones affect the ease of cultivation and if large enough or numerous enough can physically damage the equipment itself. The degree of limitations due to surface stoniness outlined are similar to those used by Greenlee (1980) for trench type sanitary landfills.
4. These separations indicate the optimum internal moisture regime necessary for deep plowing to be a success. The better drained soils have less limitation as they allow for a greater degree of downward movement of water which helps in the removal of salts out of the

profile. Poorly drained soils, because they are generally wet and receive continual additions of overland and/or subsurface water, which prevents adequate removal of salts, are given a limitation rating of severe. These soils also have a low trafficability which prevents easy access by equipment. Gleysolic soils fall into this category. Imperfectly drained soils will have a moderate limitation.

5. The soil texture separations correspond well with the soil drainage regimes. The coarse-textured soils, which have a none-slight limitation, correspond to the better drained soils which have none to slight limitations as well. Generally speaking as the soil texture becomes finer the internal drainage becomes poorer as in the situation with medium to fine textured soils which are often imperfectly drained, and have a limitation rating of moderate. The extremes in soil texture, very fine textured clay soils or the very coarse textured sandy and gravelly soils are often poorly and very poorly drained or have little or no water holding capacity at all and are rated as severe. These separations are based on the dominant soil textures within plow depth.

6. Hermans (1980) has stated that results from his research indicate that for deep plowing to work there should at least be 15 cm of C horizon material within the usual plow depth (60 cm). Therefore, if there is 15 cm or more of C horizon material present that soil is rated as having none to slight limitations. If there is less than 15 cm of material present, that soil is rated as moderate to severe in limitation. A severe rating was not given to soils with less than 15 cm of C horizon material within plow depth as some soils may have

more exchangeable calcium in 10 cm of C horizon than others have in 15 cm of C horizon material. These values are meant to act as general guidelines.

7. The placement of various parent materials into different categories of degree limitation was based on Kjearsgaard's (1980) work. He stated that till, glacio-lacustrine, lacustrine and fluvial parent materials could be deep plowed and that residual bedrock material should not be deep plowed, especially if it is sodic. These parent materials were rated as having none to slight limitations and severe limitations, respectively. Even though a parent material may be rated as having none to slight limitations, it may have to have its rating lowered if it shows saline, gleyed or other adverse tendencies.

8. A calcium content of greater than 20 meq/ℓ in the C horizon, which usually indicates the presence of calcium in the gypsum form, is considered necessary for the success of deep plowing (Sandoval 1979). Therefore, if a soil has greater than 20 meq/ℓ of calcium, it is given a none to slight limitation, if it has less than 20 meq/ℓ of calcium, then it is given a moderate to severe limitation. No severe limitation was given as it has been shown by the Soil Branch of Alberta Agriculture that some Solonetzic soils will show a good response to deep plowing with less than 20 meq/ℓ of calcium in the C horizon (Hermans 1980).

9. Cairns (1978) has stated that for good seedbed preparation in a Solonetzic soil the surface horizon should have a Ca/Na ratio of greater than 4:1. The assumption was made that the chemical conditions that make for a good seedbed could also be those for a good subsoil condition. Therefore a soil with a Ca/Na ratio of greater

than 4:1 in the surface horizon would be rated as having a none to slight limitation and a soil with a Ca/Na ratio of less than 4:1 would have a moderate to severe limitation.

10. Hermans (1980) states that a soil with a pH of less than 6 in the surface horizon should benefit from the liming effect associated with deep plowing. This fact has also been mentioned in a good deal of the early Russian literature on deep plowing. Therefore any soil with a surface pH of less than 6 should respond well to this liming effect and be given a none to slight limitation. A soil with a surface pH of greater than 6 is given a moderate limitation as there is usually sufficient amounts of calcium already present in the soil. It should be kept in mind that although a wheel-move plow is considered to be the plow used, where the topsoil is being placed back on top of the B and C horizon, the subsurface horizon is rough enough that the topsoil will filter into it to give sufficient contact between the soils for the liming action to be effective. Subsequent discing operations will also help to increase the contact between the subsoil with its higher pH and the topsoil.

11. These soil landscapes correspond to the soil drainage classes in #4. That is those soil landscapes that are commonly found in the better drained situations are rated as having a none to slight limitation. Generally speaking these soil landscapes include Chernozemic or Solonetzic Chernozems in the upper slope positions with Solonetzic soils occupying the midslope positions. Soil landscapes rated as having a moderate degree of limitation are those occupying the lower slope positions or depressional areas where the water is removed sufficiently slowly in relation to the supply to keep the

soil wet for a significant part of the growing season. Alkaline Solonetz and Gleysolic soils are given a severe rating as they occupy poorly and very poorly drained areas where the soils remain wet for the greater portion of the time that the soils are not frozen. These separations are theoretical in nature based on other researchers' work on the occurrence of Solonetzic soils in a soil landscape (Figure 1) and the author's experience of soil positions in a landscape and their relationship to a particular internal moisture regime.

RESULTS AND DISCUSSION

Description of Soilscape Groups and Soil Units

The following are descriptions of the soilscape groups and soil units as mapped in the study area. For the location of the soil units within the study site refer to the soils map at the back of this report.

Soilscape Group A

The soils of this group are dominantly Orthic Dark Gray with significant inclusions of Eluviated Black and Dark Gray Luvisols, all developed on clayey till parent material. They are located in the northeast corner of the study area (SE 28, Tp 49, R 24, W4th) on the crest and northeast facing slopes of the northwest to southeast oriented moraine bordering Saunders Lake. The moraine is characterized by an undulating surface expression on the crest and rolling to hummocky surface expression on the side slopes. The slopes vary from 5-15% from the crests to the flanks with eroded knolls occurring on the cultivated hummocks.

The Orthic Dark Gray soils of the crest and upper slope positions have an Ap/Ah horizon of variable thickness, ranging from 15 to 25 cm. The Eluviated Black soils found on the crest have thicker Ap/Ah horizons (25 to 38 cm) with intermittent Ae horizons, while the Dark Gray Luvisols on the northeast flank have thinner surface horizons (10 to 15 cm) with a pronounced continuous Ae horizon.

The dominant soils of this group have at least 15 cm of C horizon

material which occurs at a depth of 75 cm and are well drained. The surface pH averages 6.3, with a soluble Ca/Na ratio from 6.0 to 6.5 and a calcium content from 8.1 to 8.7 meq/ℓ in the C horizon. (Detailed descriptions of criteria to be considered when deciding whether or not to deep plow, for all soil units described in this section, appear in Appendix 4). The soils of this soilscape group are medium textured.

This soilscape group includes two soil units, A1 and A2 (Figure 3). Soil Unit A1 is located on the more gently sloping crest area with Soil Unit A2 occurring on the rolling to hummocky northeast facing flank. Although each unit occurs as one polygon on the map they are significantly different from the rest of the soil units of the area. Differences in the microclimate and vegetation are reflected in differences in the significant components of the units.

Soil Unit A1

Orthic Dark Gray soils are the dominant soil of this unit and occupy the relatively cooler, more moist positions. These soils correlate to the Falun soil series as described by Bowser et al (1962). Eluviated Black soils which comprise the significant component occupy the higher recharge position of the unit. This unit occupies the upper slope to crest positions of the landscape (Figure 3).

Presently this unit is being utilized as pastureland.

Soil Unit A2

This unit is similar to Unit A1 in its dominant component but in

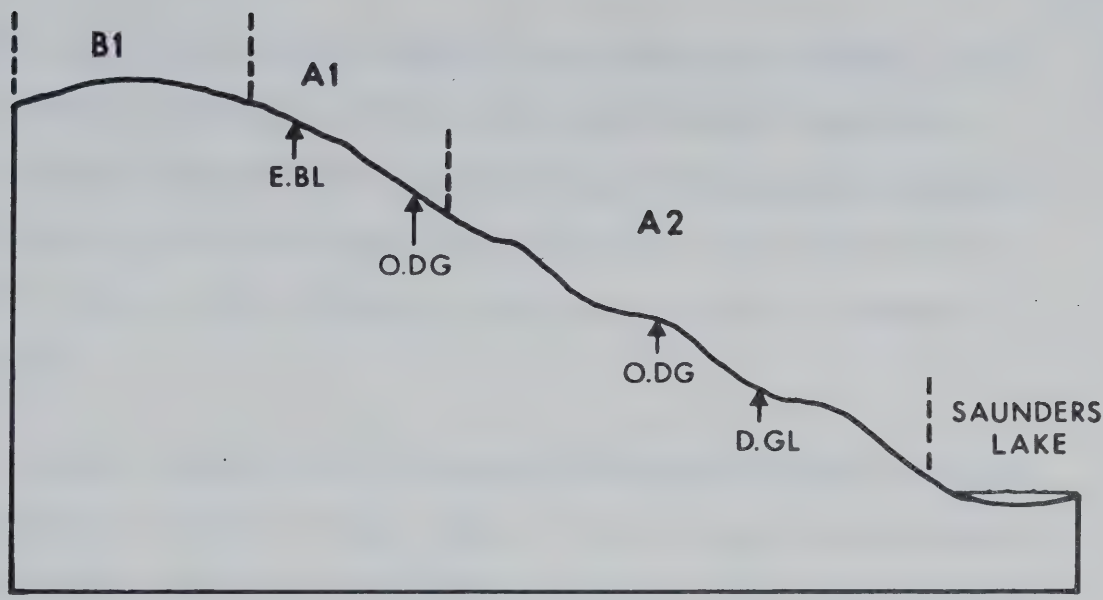


FIGURE 3: Landscape Position of Soil Units A1 and A2 within Soilscape Group A. Soil subgroups are designated by accepted abbreviations (Canada Soil Survey Committee 1978).

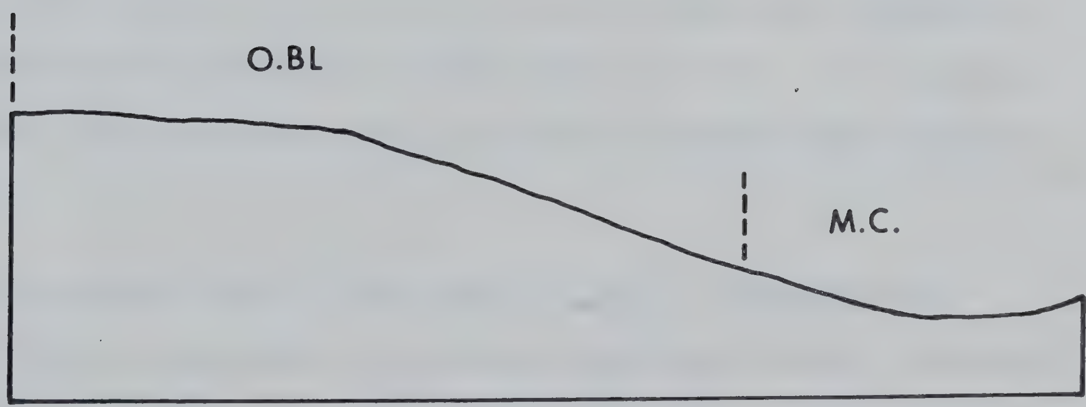


FIGURE 4: Landscape Position of Soils within Soil Unit B1 (M.C. designated various minor components as described in the text).

this case Dark Gray Luvisols comprise the significant component. The Orthic Dark Gray soils are found on the tops of eroded knolls and warmer upslope positions while the Dark Gray Luvisols occupy the relatively cooler, more moist lower slope positions. This unit occurs in the mid to lower slope positions of the area on rolling to hummocky topography.

Presently the more gently sloping portions of this unit are under cultivation and seeded to cereal crops. On the steeper slopes leading down to Saunders Lake the land has been left in a treed state dominated by Aspen Poplar and White Spruce.

Soilscape Group B

Orthic Black and Eluviated Black soils developed on clayey-skeletal till are the dominant soils of this group. The members of this group occur extensively throughout the study area with the exception of the southeast corner which is an area of soils development primarily on glacio-lacustrine and residual bedrock parent material. The topography associated with this group ranges from level to hummocky with slopes 0.5 to 9%.

The dominant soils of this group are well to moderately well drained with the significant soils being imperfectly drained. The minor soil inclusions within soil units of this group vary from well drained Chernozemic soils to poorly drained Gleysolic soils. The surface horizons of the Orthic and Eluviated Black soils vary in thickness from 10 cm in the upper slope positions to 30 cm in the lower slope positions.

The surface pH's of the dominant soils within this group vary from 5.9 to 6.4, the Ca/Na ratios from 4.4 to 8.5 and the calcium content in the C horizon from 4.1 to 6.5. The depth of C horizon material within plow depth ranged from 5 to 35 cm.

Presently soils within this soilscape group are used primarily for the production of cereal crops.

Soil Unit B1

Orthic Black soils occupying the relatively drier mid to upper slope positions comprise the dominant component of this unit. Eluviated Black soils which have developed in the lower slope positions where accumulation of snowmelt and surface runoff have leached the soil sufficiently to enhance the development of an Ae horizon, and Gleyed Black, Rego Black, Gleyed Rego Black and Orthic Humic Gleysols which develop in depressional (pothole) areas within the unit comprise the minor component of this unit (Figure 4).

The surface horizon of these soils which are medium textured is variable in thickness ranging from 15 to 25 cm for the dominant soils to 10 to 15 cm for the soils of the minor component.

Soils of this unit are presently being utilized for cereal production.

Soil Unit B2

Medium-textured Eluviated Black soils developed in the better

drained upslope positions are dominant in this unit. Gleyed Eluviated Black soils and Rego and Orthic Humic Gleysols developed on poorer drained fine-textured recent alluvium comprise the minor component of this unit (Figure 5). The latter occupy the lower slope to depressional areas within the unit.

The surface horizons of the Eluviated Black soils ranged in thickness from 15 to 25 cm.

This unit occurs in association with other Chernozemic, Solonetzic or Gleysolic soil units but does not occur in association with any particular soil unit.

Soil Unit B3

Orthic Black soils, similar to those of unit B1 and occupying the mid to upper slope positions, are dominant in this unit. Black Solonetz and Gleyed Eluviated Black soils are the significant and minor components, respectively, of this unit (Figure 6).

This unit is not extensive. It occurs primarily in association with units B2 and B4 both of which have well-drained Eluviated Black soils as their dominant component and both occur at higher elevations than unit B3.

Soil Unit B4

Medium-textured Eluviated Black soils which are dominant in this unit occupy the mid to upper convex slope position where internal soil

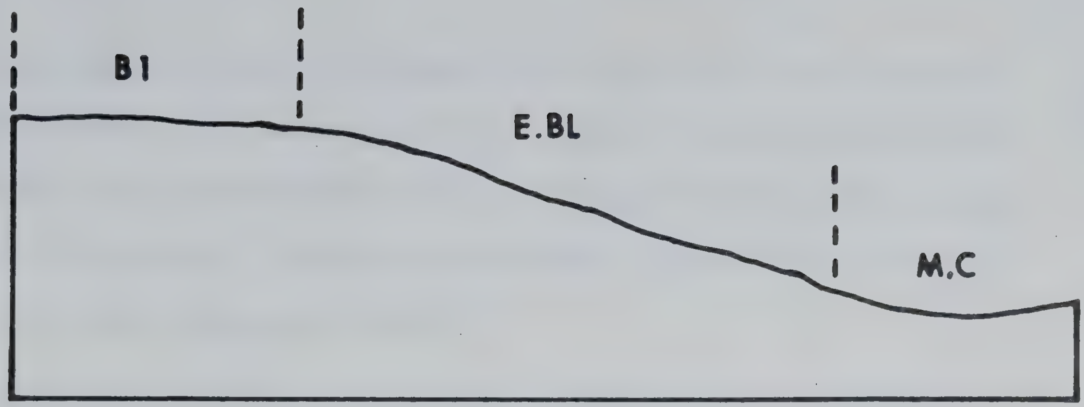


FIGURE 5: Landscape Position of Soils within Soil Unit B2

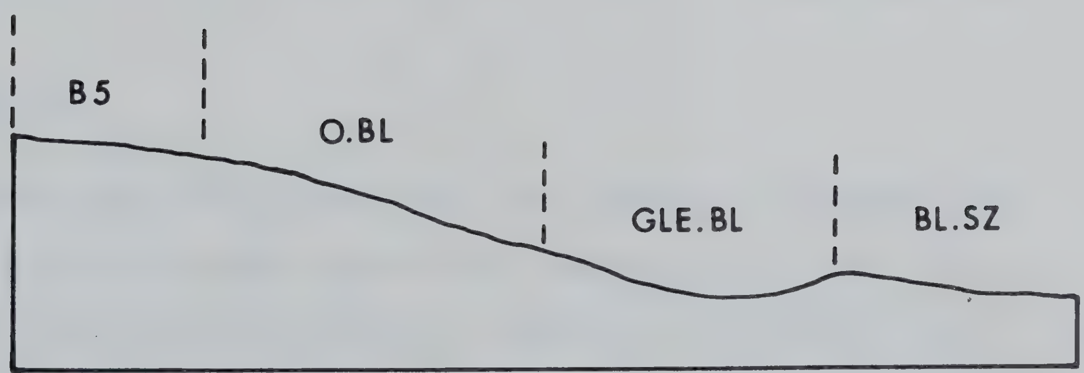


FIGURE 6: Landscape Position of Soils within Soil Unit B3

drainage is better. Gleyed Eluviated Black soils which have developed in poorer drained lower slope positions, comprise the significant component, and carbonated Eluviated Black and Gleyed Eluviated Black soils and Orthic Black soils, occupying depressional areas within this unit, comprise the minor component (Figure 7).

Unlike any other unit within this soilscape group, these soils have developed on a sandy clay loam to sandy loam-textured fluvial veneer (45-65 cm) overlying clay loam-textured till material.

This unit is not widespread throughout the study but due to its unique nature it has been separated from other units. It occurs in association with other Chernozemic soil units but not with any particular unit. Within the study site this unit is located in old drainage ways.

Soil Unit B5

Orthic Black and Eluviated Black soils comprise the dominant component and occupy the mid to upper slope positions of this unit. Gleyed Black and Gleyed Eluviated Black soils constitute that portion of the minor component developed on till similar to that of the dominant soils. The remainder of the minor component, Rego Humic Gleysols, carbonated, have developed on fine to medium-textured recent alluvium (Figure 8).

Soil unit B6 is widespread throughout the study site and occurs in association with other Chernozemic units (B1 and B2), as well as, Gleysolic and Solonetzic soil units.

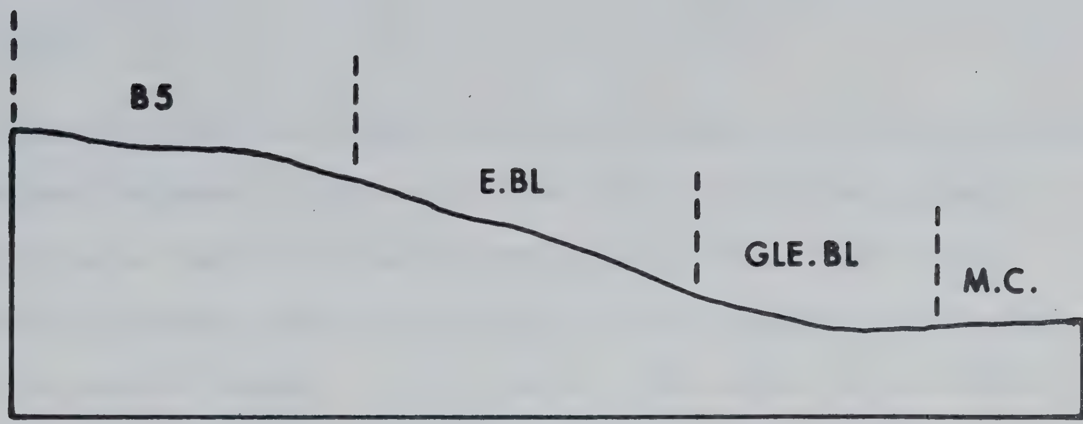


FIGURE 7: Landscape Position of Soils within Soil Unit B4

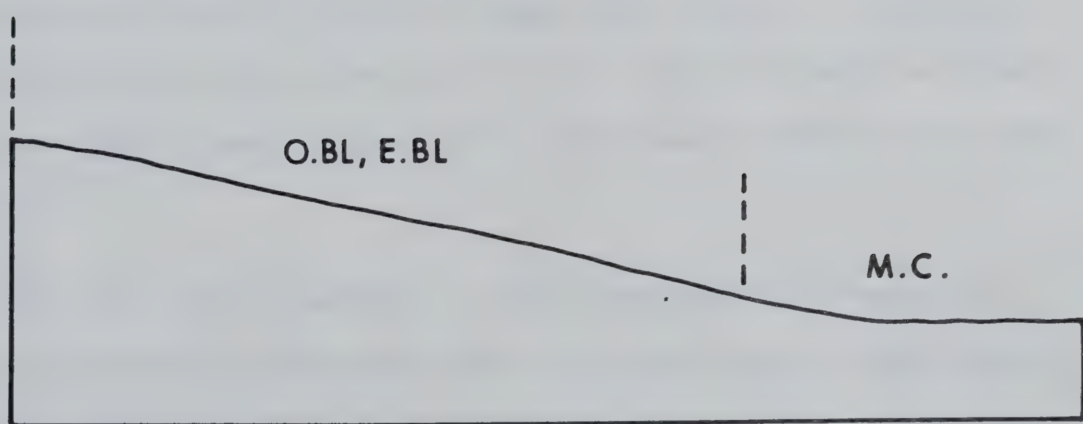


FIGURE 8: Landscape Position of Soils within Soil Unit B5

Soil Unit B6

Similar to Unit B5, Orthic Black and Eluviated Black soils comprise the dominant component of this unit. The soils of the minor component (Black Solonetz, Black Solodized Solonetz and Solonetzic Black soils) indicate the variable sodium concentration in the groundwater in the area where this unit is located. It is a result of the effect of this sodic groundwater on soil development that this unit was separated from unit B5.

The catenary sequence of this unit shows that the Orthic Black and Eluviated Black soils develop in the better drained middle and upper slope positions. As the presence of sodium in the groundwater becomes increasingly dominant, the soils change from the Orthic Black and Eluviated Black soils of the mid to upper slope position to Solonetzic Black soils in the lower slope position to the Black Solonetz and Black Solodized Solonetz found in the level to depressional areas of this unit (Figure 9).

This unit occurs primarily in the transition zone between the areas of predominantly Chernozemic soil units and those of predominantly Solonetzic soil units.

Soil Unit B7

Eluviated Black soils developed on a till veneer overlying residual bedrock material, which Kjearsgaard (1980) refers to as "soft rock", comprise the dominant component of this unit (Figure 10). The

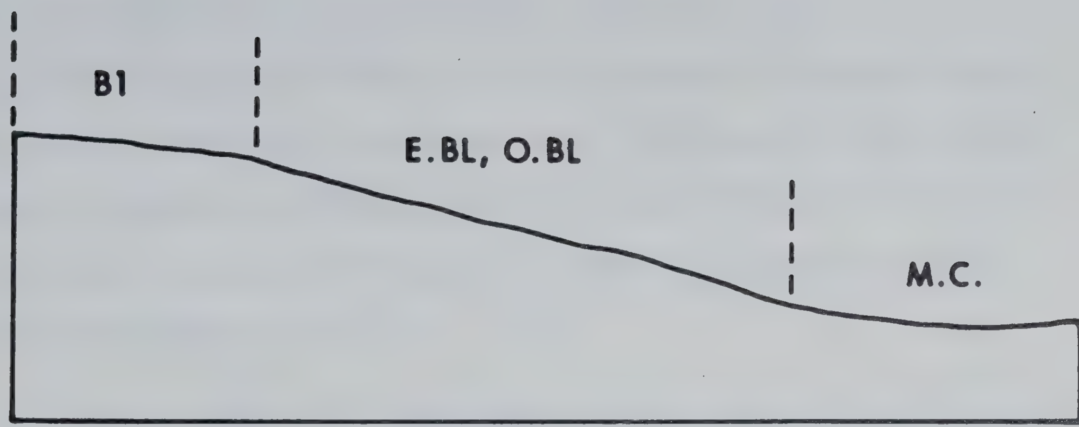


FIGURE 9: Landscape Position of Soils within Soil Unit B6

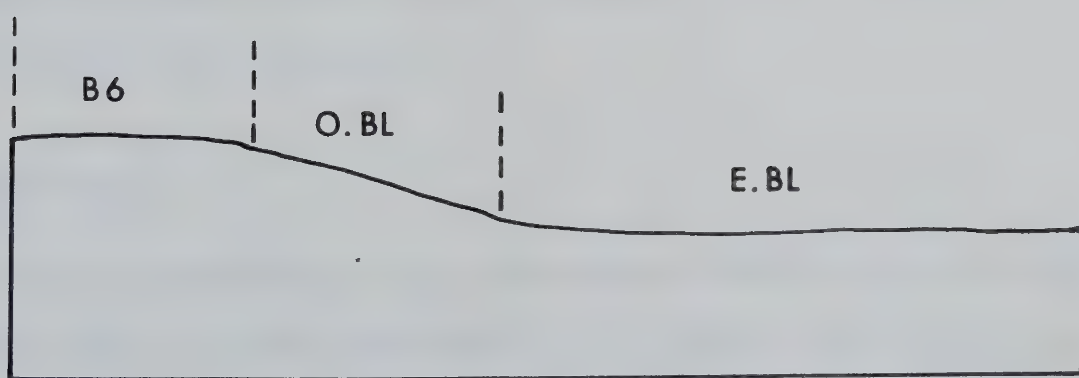


FIGURE 10: Landscape Position of Soils within Soil Unit B7

lithological discontinuity in the profile occurs at a depth of 35 to 40 cm from the surface and is marked by the appearance of weathered bedrock in the profile. This unit abutts an area of predominantly till material. As a result, pockets of till show up in this unit. These are accounted for in the minor component of this unit, which is comprised of Orthic Black soils developed on till.

This unit occurs in a topographically lower position than units with which it is associated, the latter are usually developed on till material. This relationship explains the till veneer.

This unit is found in association with unit B2 and as well may be bordered by Gleysolic soil units developed on lacustrine material. The areal extent of this unit is not large and occurs in isolated locations throughout the study site but are significantly different in mode of deposition and require separation.

Soilscape Group C

Similar to Soilscape Group B, the dominant soils of this group are Eluviated Black and Orthic Black soils. This group was established to represent the differences in parent materials between the two, with the soils of Soilscape Group C being developed on stone-free clayey glacio-lacustrine material.

The dominant soils of this group are fine to medium-textured and well to moderately-well drained. They occur on level to gentle topography. The remainder of the soils within this unit are similar in

texture but occur in the poorer drained sites on level to depressional topography.

Surface horizons range in thickness from 15-30 cm with a pH that ranges from 6.0 to 6.5. The average depth of C horizon material within plow depth is 5-10 cm. The calcium content in the C horizon and the Ca/Na ratio in the surface horizon varies from 4.1 to 6.0 and 4.5 to 9.0, respectively.

Geographically the soil units of this group occur sporadically throughout the study site, usually in association with other Chernozemic or Solonetzic soil units.

Presently these soils are used for the production of cereal crops.

Soil Unit C1

Orthic Black soils which occur in the elevated slope positions of this unit comprise the dominant component. The lower slope positions where Solonetzic soil processes are dominant are occupied by Black Solonetz, the minor soil component (Figure 11).

This unit is not extensive and occurs in small isolated locations in association with other Chernozemic soil units (B3 and B5) as well as Gleysolic and Solonetzic soil units.

Soil Unit C2

Similar to soil unit B5, the dominant soils of this unit are Orthic Black and Eluviated Black soils while the minor component soils

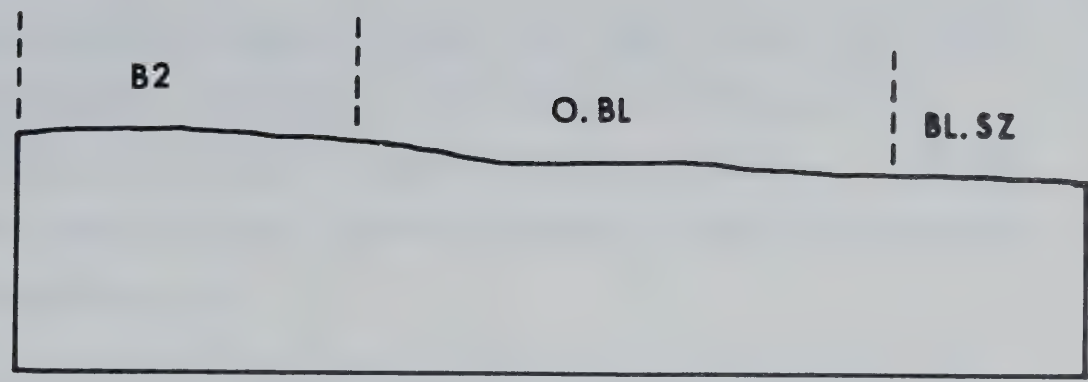


FIGURE 11: Landscape Position of Soils within Soil Unit C1

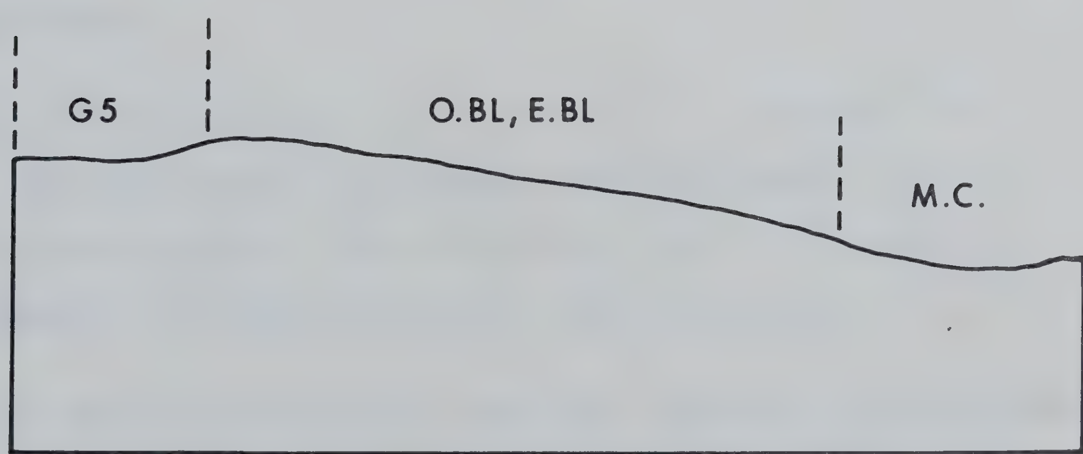


FIGURE 12: Landscape Position of Soils within Soil Unit C2

are Gleyed Black and Gleyed Eluviated Black soils and Rego Humic Gleysols, carbonated. The dominant soils are well to moderately-well drained and occur on level to gently undulating topography. The minor component soils are poorly drained and develop on level to depressional topography (Figure 12).

There is a considerable amount of variability in surface horizon thickness with the depressional areas usually having slightly thicker A horizons due to the overland movement of topsoil by water.

Like unit C1, this unit is not widespread throughout the study site and occurs primarily with other Chernozemic soil units.

Soilscape Group D

The dominant soils of this group belong to the Solonetzic soil order. The separation of this group from Soilscape Groups E and F is based on parent material. Soils of Soilscape Group D are developed on clayey-skeletal calcareous till material which may be saline.

Soil units belonging to this group occur throughout the study site on ground moraines with slopes ranging from 1-5%. The majority of the units though occur in the south-central and southeastern sections of the study area where Solonetzic soils are dominant.

The thickness of the Ap/Ah horizon and the depth to C horizon material associated with these units is variable. Generally there is a greater thickness of Ap/Ah horizon (15-20 cm) and a greater depth to C horizon material (30-40 cm) associated with the Black Solonetz and

Black Solods of this unit than the Black Solodized Solonetz which have a relatively thin surface horizon (5-10 cm) with the C horizon material appearing at a depth of less than 30 cm.

Internal drainage is variable, ranging from poorly and imperfectly drained to moderately well and well drained, medium-textured soils. Within the dominant soils of this group surface pH varies from 6.0 to 6.6, the calcium content (meq/ℓ) in the C horizon from 5.6 to 21.4 and the Ca/Na ratio in the surface horizons from 0.3 to 4.5.

Land use on soils of this group varies from cereal production to pasture.

Soil Unit D1

The dominant soils of this unit are a complex of Black Solods and Solonetzic Black soils occupying mid to upper positions. Eluviated Black soils and Gleyed Black Solods and Black Solonetz, occupying the upper slope and level areas within the unit comprise the significant and minor soil components of this unit, respectively (Figure 13).

This unit appears as a transitional unit between areas of primarily solonetzic soils and those of chernozemic soil and as such is not widespread. It occurs in close proximity to several of the deep plowing sites within the study area.

Soil Unit D2

Black Solonetz, occupying the mid to lower slope positions, com-

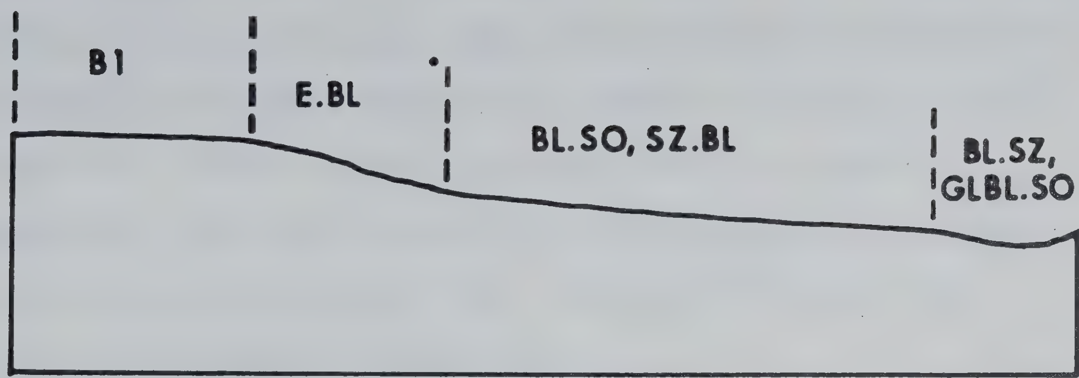


FIGURE 13: Landscape Position of Soils within Soil Unit D1

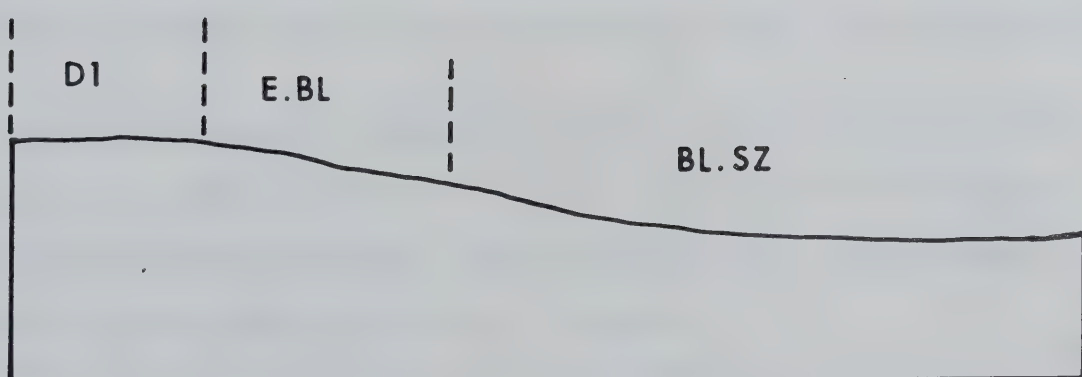


FIGURE 14: Landscape Position of Soils within Soil Unit D2

prise the dominant component of this unit. Similar to unit D1 Eluviated Black soils, occupying the upper slope positions, comprise the significant component of this unit (Figure 14). However, unlike unit D1 this unit shows up in several different locations and is not restricted entirely to the transition zone between the two different soil orders. Soil Unit B3 which has Solonetzic soil inclusions is the unit most often found in association with unit D2.

Soil Unit D3

Black Solonetz, occupying the mid to lower slope positions, comprise the dominant soils of this unit. Orthic Black and Eluviated Black soils in the upper slope positions and Orthic Humic Gleysols, which may show signs of salinization, in the depressional areas of this unit comprise the significant and minor soil components, respectively (Figure 15).

Cultivation and the subsequent disruption of the Ae horizon make it difficult to assess whether or not both of the soils of the significant component exist in this unit and in what portion. To compensate for this, they have been described as a complex.

This unit occurs in the southern half of the project area in association with both Chernozemic and Solonetzic soil units such as B1, B6, D4 and D5. When this unit occurs with chernozemic units they occupy topographically lower positions.

Soil Unit D4

Black Solonetz, occupying the slightly drier level areas within

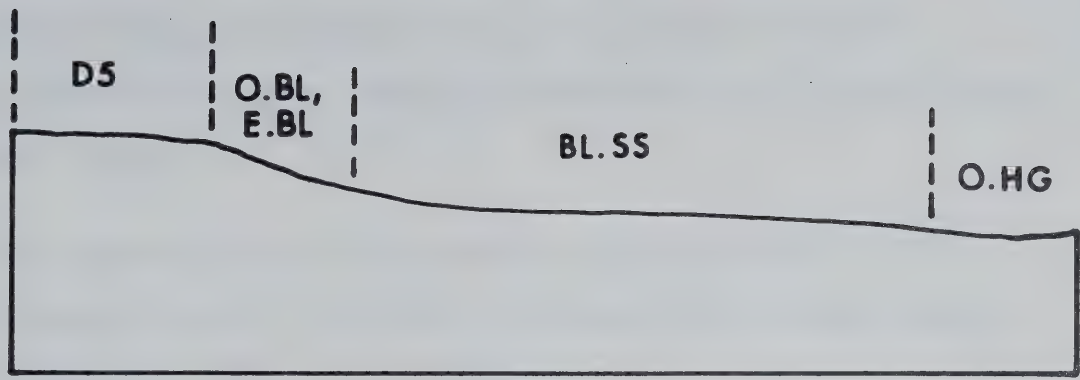


FIGURE 15: Landscape Position of Soils within Soil Unit D3

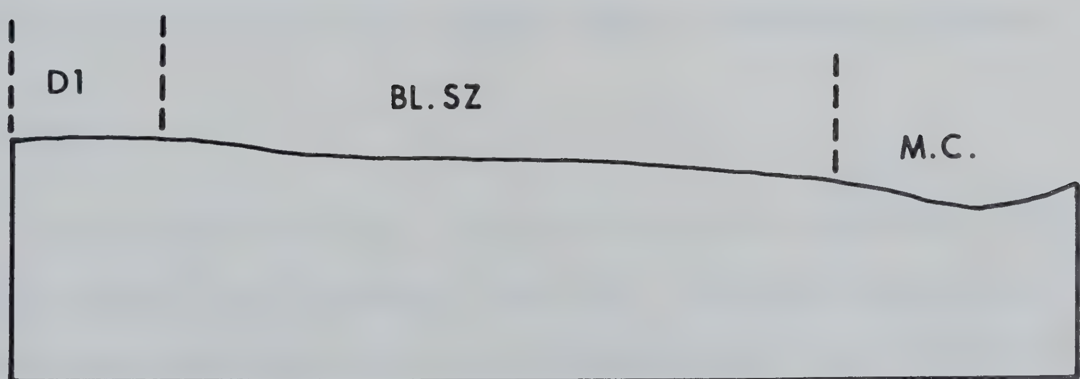


FIGURE 16: Landscape Position of Soils within Soil Unit D4

this unit, comprise the dominant component. The minor component, occupying the wetter depressional areas, is a complex of Black Solods, Gleyed Black Solods, Alkaline Solonetz and Orthic Humic Gleysols, carbonated (Figure 16).

The dominant soils of this unit are morphologically similar to those of units E2 and F1. The basis for separation is on the kind of parent material.

This unit is widespread throughout the study site and occurs in association with Chernozemic, Solonetzic or Gleysolic soil units. Units B6, D1, D5 and G2 are found in conjunction with this unit.

When in association with Chernozemic soil units, soils of this unit occupy topographically lower positions, while in association with Gleysolic soil units they occupy slightly higher topographic positions.

Soil Unit D5

Black Solodized Solonetz, occupying the mid-slope positions, comprise the dominant soil component of this unit. Solonetzic Black soils, located in the upper slope positions and Black Solonetz located in the lower slope to level positions comprise the significant and minor soil components, respectively (Figure 17).

This unit occurs in several locations in areas of both Chernozemic and Solonetzic soil units. The dominant soils are morphologically similar to those of unit D3, both of which show a shallow profile (often less than 30 cm) overlying a calcareous, sometimes saline, parent material.

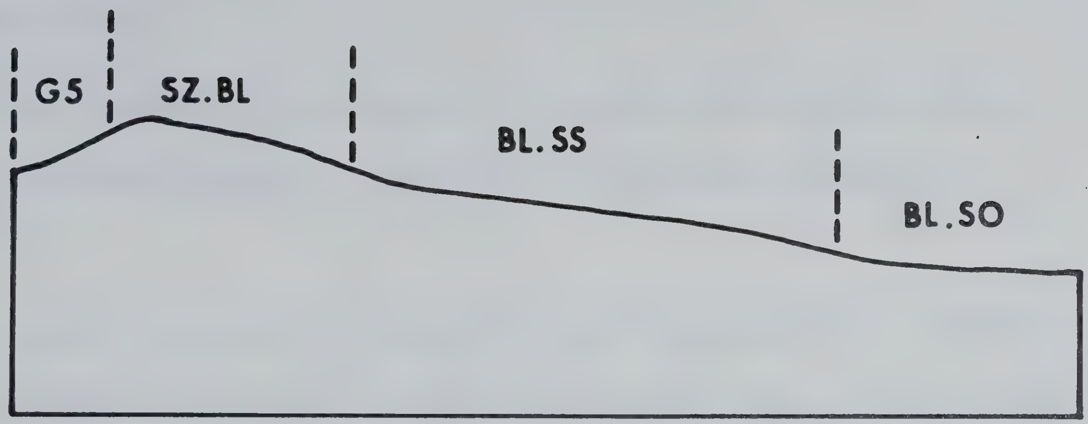


FIGURE 17: Landscape Position of Soils within Soil Unit D5

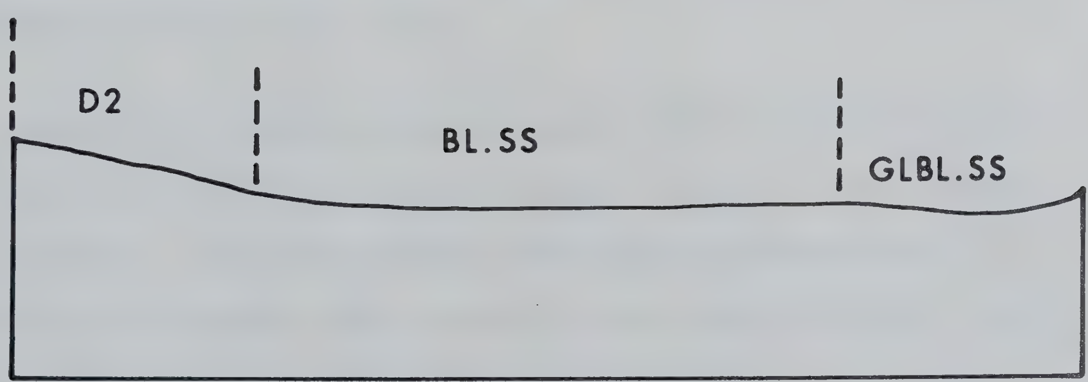


FIGURE 18: Landscape Position of Soils within Soil Unit El

Soilscape Group E

The dominant soils of this group belong to the Solonetzic soil order. They are developed on stone-free clayey glacio-lacustrine material.

The soil units of this group are found predominantly on level to gentle slopes in the southeast portion of the study site. Soils of unit E3, however, develop in depressional areas.

The thickness of the medium-textured Ap/Ah horizons is variable ranging from 3-10 cm for the Black Solodized Solonetz, to 7-12 cm for the Black Solonetz to 10-20 cm for the Alkaline Solonetz which receive soil additions from overland runoff. All of the dominant soils are characterized by a relatively shallow depth to a calcareous C horizon, usually within 45 cm of the surface.

The pH of the surface horizons ranges from 6.1 to 6.2, the Ca/Na ratio from 0.4 to 8.0, and the calcium content (meq/ℓ) in the C horizon from 7.0 to 23.1. Alkaline Solonetz, which are the dominant soil of unit E3 have the highest Ca/Na ratio and highest calcium content (meq/ℓ) in the C horizon of any of the Solonetzic soil units.

The internal drainage of the dominant soils range from imperfectly drained Alkaline Solonetz to moderately well to well drained Black Solonetz and Black Solodized Solonetz. The Alkaline Solonetz are found in discharge areas.

Soil units of this group occur primarily in association with other Solonetzic soil units. Presently soils of this group are being utilized

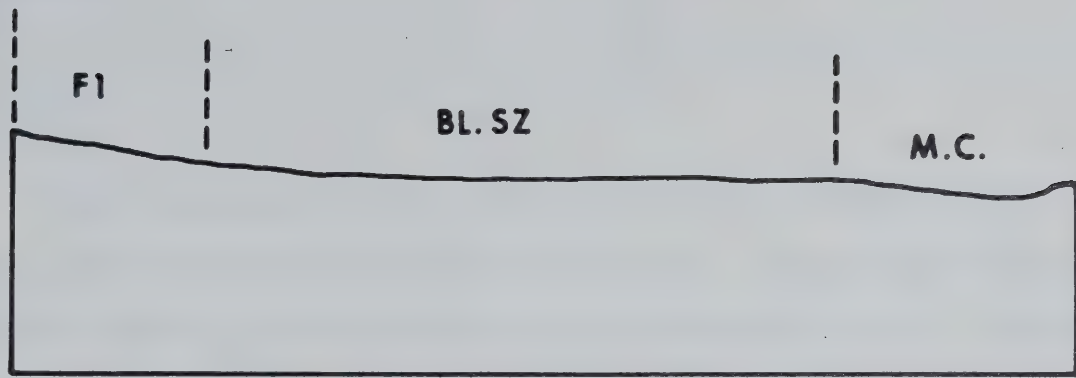


FIGURE 19: Landscape Position of Soils within Soil Unit E2

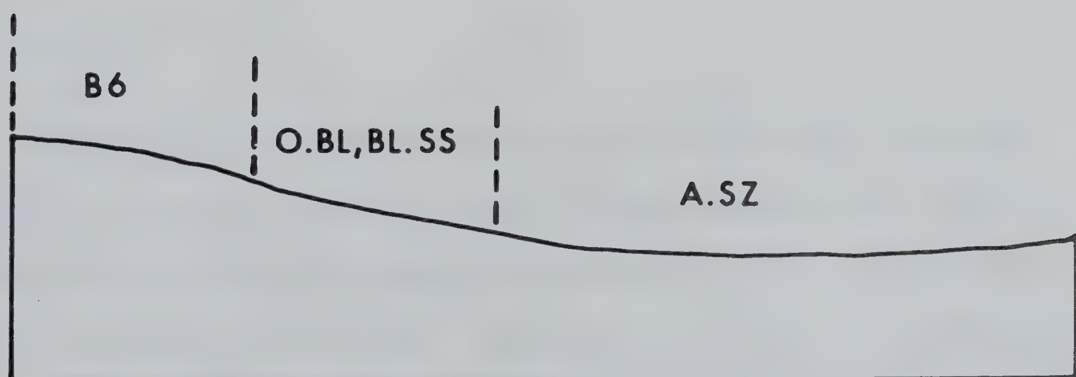


FIGURE 20: Landscape Position of Soils within Soil Unit E3

as pasture.

Soil Unit E1

Black Solodized Solonetz, occurring on level to nearly level slopes, comprise the dominant soils of this unit. Gleyed Black Solodized Solonetz, occurring in depressional areas within this unit, are the minor inclusions (Figure 18). They are subject to significant annual fluctuations of the water table within their solum, that result in the development of mottles within the profile.

Geographically within the study area this unit is found mainly around the townsite of Kavanagh, and is associated with units B1, D2, D3, F1, G3 and G4.

Soil Unit E2

Black Solonetz are the dominant soils of this unit. The minor component is a complex of Gleyed Black Solods, Black Solods, Alkaline Solonetz and Orthic Humic Gleysols, carbonated, found in the depressional areas of this unit (Figure 19). The nature of the soils comprising the minor component indicates the variable salt content of the groundwater in this area. Consequently, this unit will occur in association with soil units dominated by soils of other orders. Similar to unit E1 this unit does not occur with any particular unit but is found in association with units B2, B6, C2, D1, D2, D3, D4, F1, G2 and G4.

Soil Unit E3

The dominant soils of this unit are Alkaline Solonetz, occupying

depressional areas within this unit. Occupying the drier upslope portions of the unit are Orthic Black soils and Black Solodized Solonetz, which comprise the minor component (Figure 20).

This unit is located in the northeast corner of the study site in an area of Chernozemic soil units. This association is indicated by the presence of Orthic Black soils as part of the minor component.

The Alkaline Solonetz of this unit is characterized by a dark organically stained solum. The staining is a result of a large concentration of sodium salts, in the profile, dissolving the organic matter which is subsequently leached down the profile.

This unit is found in association with units B1, B6, D4 and E2.

Soilscape Group F

Similar to Soilscape Groups D and E, the dominant soils of this group belong to the Solonetzic Soil Order. The soils of this group, however, are developed on clayey-skeletal residual bedrock material, which appear as small fragments of weathered bedrock throughout the lower portion of the soil profile. The internal drainage of soils within this group ranges from poorly drained in the depressional areas to well drained in the upper slope positions.

The surface expression of the land associated with this group is similar to that of Soilscape Groups C and E which developed on glacio-lacustrine materials. Soils of this group are found in the southeastern portion of the study area, an area of predominantly glacio-lacustrine

material, where bedrock is near the surface.

The dominant soils of this group are medium-textured and moderately well drained. Surface horizon pH's vary from 6.2 to 6.5, the Ca/Na ratio from 0.8 to 5.1 and the calcium content (meq/ℓ) in the C horizon from 11.2 to 13.1. The depth to C horizon material is approximately 20 cm and there is at least 15 cm of C horizon material within the normal depth of deep plowing.

Soil units within this group occur mainly in association with other Solonetzic soil units. They do, however, occur with Chernozemic or Gleysolic units. When they occur with Chernozemic soil units, they occupy slightly lower topographic positions; when they occur with Gleysolic soil units, they occupy slightly higher topographic positions.

Scattered throughout this soilscape are pockets of till material occurring as slightly higher areas within a particular unit.

Presently this land is used for pasture.

Soil Unit F1

Black Solonetz and Black Solodized Solonetz, occupying the lower slope positions of this unit, comprise the dominant component. The minor component is comprised of Solonetzic Black and Eluviated Black soils occupying the relatively drier upslope positions (Figure 21).

The dominant soils of this group are morphologically similar to those of soil units D1, D2, D3, D4, D5, E1 and E2, however, soil profiles

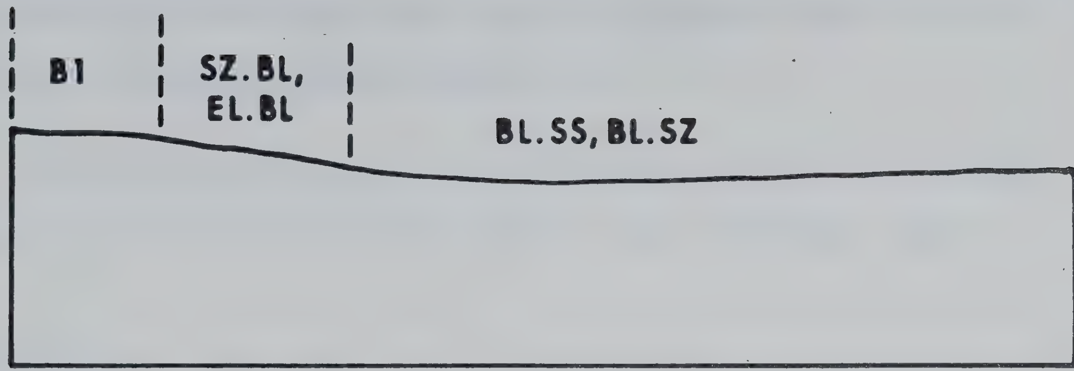


FIGURE 21: Landscape Position of Soils within Soil Unit F1

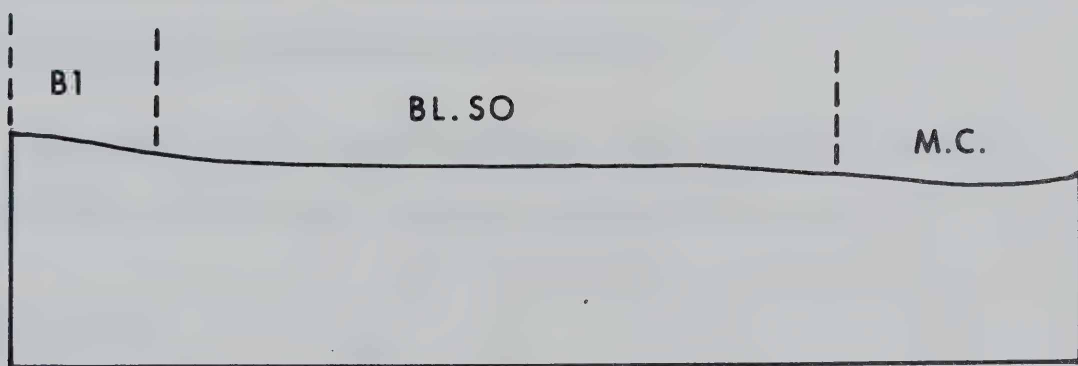


FIGURE 22: Landscape Position of Soils within Soil Unit F2

of this unit are usually shallowed with the calcareous parent material appearing at a depth of approximately 20 cm.

This unit is restricted to the vicinity of the town of Kavanagh and may occur associated with soil units of other soilscape groups.

Soil Unit F2

Black Solods, occupying the drier better drained portions of this unit are the dominant soils. Gleyed Black Solods, Alkaline Solonetz and Orthic Humic Gleysols, carbonated, comprising the minor component of this unit, are developed on medium-textured till material in depression which occur as pockets throughout the unit (Figure 22).

Similar to unit F1, the Black Solods of this unit have a shallow solum (20 cm) over a calcareous parent material.

This unit occurs in the transitional zone between areas of predominantly till material and those of glacio-lacustrine material.

Soilscape Group G

Soilscape Group G is a compilation of soil units with the dominant soils belonging to the Gleysolic Soil Order. They have developed on a number of different parent materials.

Soil units of this group are widespread throughout the study site. They occur in areas of glacio-lacustrine, till or residual bedrock materials in association with Chernozemic and/or Solonetzic soils. These soils are found in depressional areas where the water table is close to the soil surface for a significant part of the year.

Soils of this group develop over a range of poorly-drained calcareous parent material, including fine to medium textured fluvial, lacustrine and glacio-lacustrine materials. This material may be saline and mottles are common through the solum.

While the dominant soils are Gleysolic there are inclusions of Chernozemic soils occupying the better drained portions of the soil units.

Horizon thickness and depth to parent material are variable but are often similar to the zonally normal soil surrounding them. Chemical data are not available for these soil units as they are considered to already have severe limitations due to poor internal drainage.

Soils of this group are left as pastures.

Soil Unit Gl

The dominant soils of this unit are Rego Humic Gleysols developed on loamy fluvial material. The minor component is comprised of Gleyed Eluviated Black soils developed on loamy fluvial material overlying clayey-skeletal till material.

The soils of this unit occupy areas that appear in the field as old stream channels where running water had slowed down and deposited its material. These areas may be flooded in the early part of the year. This results in a situation where the bottom and lower slopes of these channels are covered by a veneer of coarse-textured fluvial material overlying till. In the mid to upper slopes, the fluvial veneer is thinning out and the underlying till, which is prevalent in the area, is

beginning to appear. The soils are progressing toward the zonally normal soils at this point (Figure 23).

The Rego Humic Gleysols of this unit have a variable Ah horizon thickness ranging from 17-45 cm overlying a calcareous parent material.

Soil Unit G2

Humic Luvic Gleysols developed on fine to medium-textured fluvial material comprising the dominant component, occupy the depressional areas within this unit. The minor component is a complex of Gleyed Black and Gleyed Eluviated Black soils developed on fluvial material occupying the slightly better drained areas of the unit (Figure 24).

This unit is not extensive. It occurs primarily in the northeast corner of the study site in association with the soil units of Soilscape Group A.

As with soil unit G1, this unit occurs primarily in association with Chernozemic soil units.

Soil Unit G3

Orthic Humic Gleysols and Rego Humic Gleysols, saline, developed on clayey lacustrine material, comprise the dominant and minor components of this unit, respectively (Figure 25). These soils have developed in depressional areas where water has ponded and deposited its sediment. Soils of the minor component show evidence of saline conditions with the presence of salt crystals in the lower horizons. However, they occur in

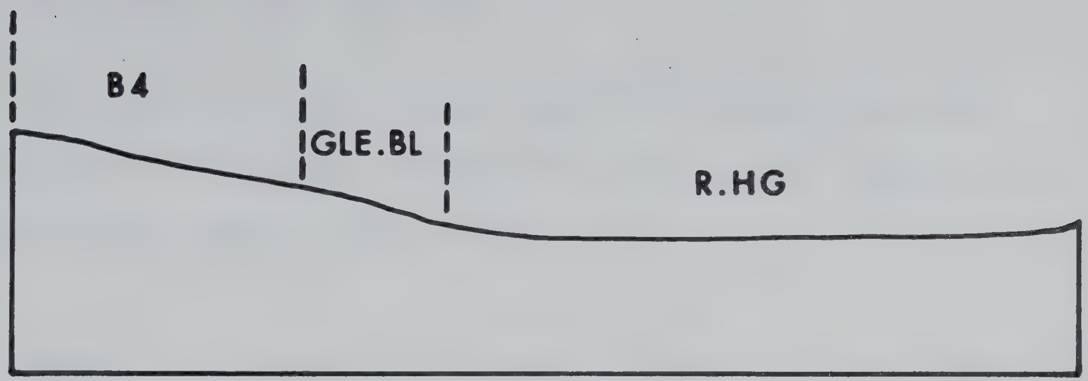


FIGURE 23: Landscape Position of Soils within Soil Unit G1

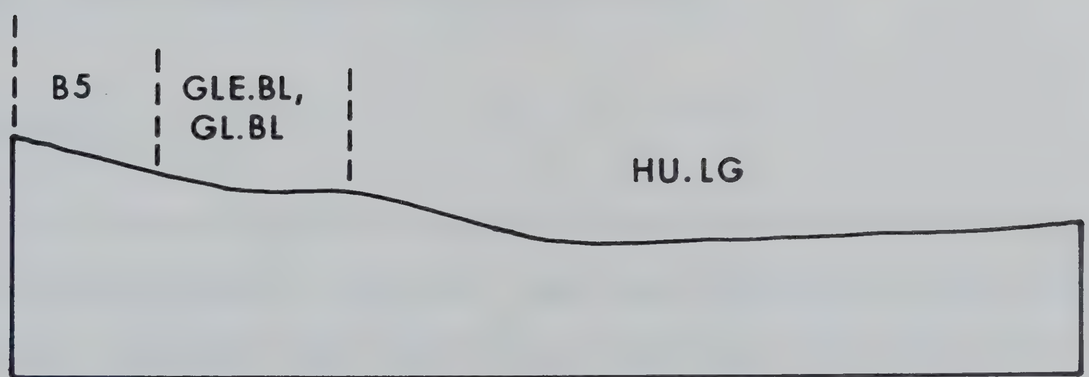


FIGURE 24: Landscape Position of Soils within Soil Unit G2

only minor amounts within this unit.

This unit is not extensive and occurs in the transition zone between areas of Chernozemic and Solonetzic soils. It is found in association with units B3, B4, D2, D5 and E1.

Soil Unit G4

Similar to soil unit G1, the dominant component of this unit is comprised of Rego Humic Gleysols. Orthic Humic Gleysols comprise the significant component of this unit. Both are developed on clayey glaciolacustrine material in depressional areas within the unit (Figure 26).

These units, like unit G3, are located in the transition zone between areas of Chernozemic and Solonetzic soils.

Soil Unit G5

Orthic Humic Gleysols developed on loamy fluvial deposits comprise the dominant component of this unit. Rego Humic Gleysols constitute the significant component, while Rego Gleysols and Gleyed Black soils comprise the minor component; all developed on loamy fluvial material (Figure 27).

The Gleysolic soils of this unit occur in the depressional portions of the landscape associated with this unit while the Chernozemic member of the unit occurs in the upper slope positions where internal drainage is better.

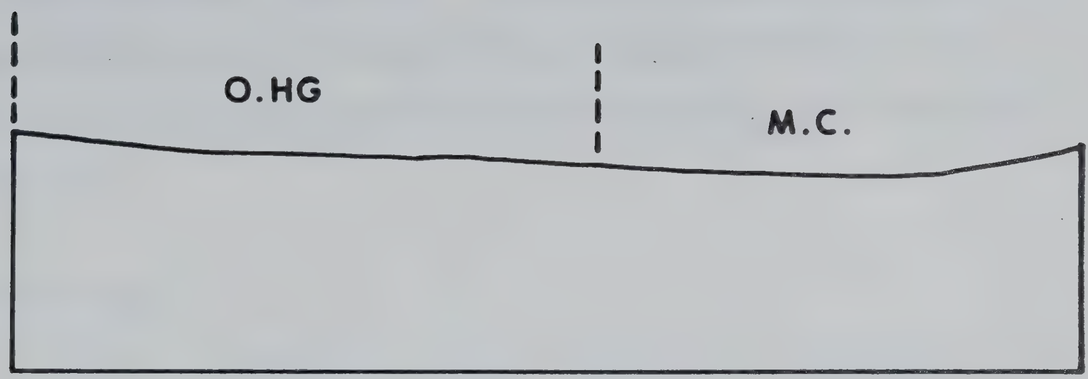


FIGURE 25: Landscape Position of Soils within Soil Unit G3

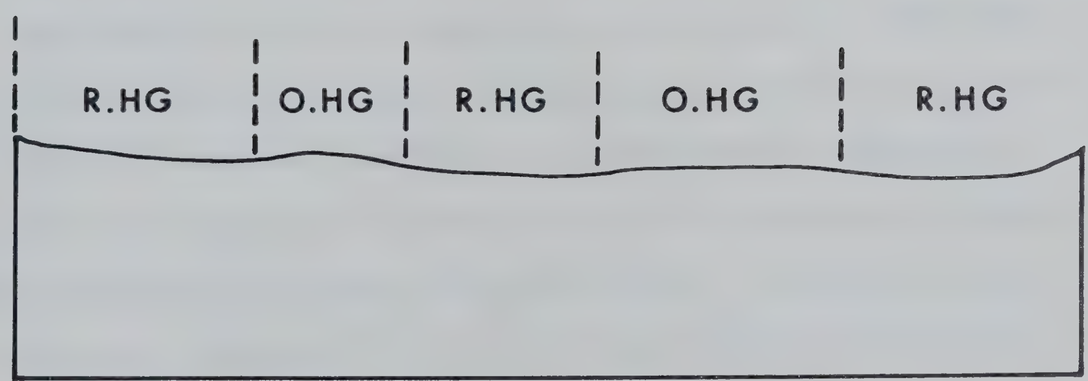


FIGURE 26: Landscape Position of Soils within Soil Unit G4

This unit is not widespread. It occurs in only one location as an abandoned stream channel traversing several sections of land. As a result it comes in contact with a number of Chernozemic soil units (B1, B2, B5 and B6).

Soilscape Group H

Organic soils dominate this group. They form in relatively cool, wet, depressional areas and are poorly drained.

Chemical data are not available for this unit as it was considered as having severe limitations due to poor internal drainage.

Soil Unit H1

Typic Mesisols are the dominant soils of this group. They form in the bottom of depressional areas. Terric Mesisols comprise the significant component. They have developed at the edges of the depression. Both soils are characterized by having 70-90 cm of moderately decomposed organic matter in their middle and surface tiers. In the case of the Terric Mesisol it overlies fine textured mineral material (Figure 28).

These soils have little agricultural value and are presently being utilized for pasture.

They occur in only one location in the study site and are surrounded by Chernozemic soils.

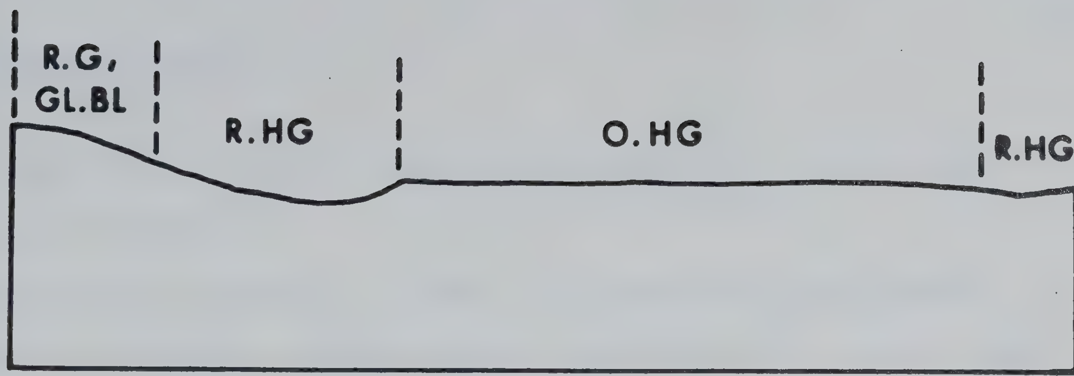


FIGURE 27: Landscape Position of Soils within Soil Unit G5

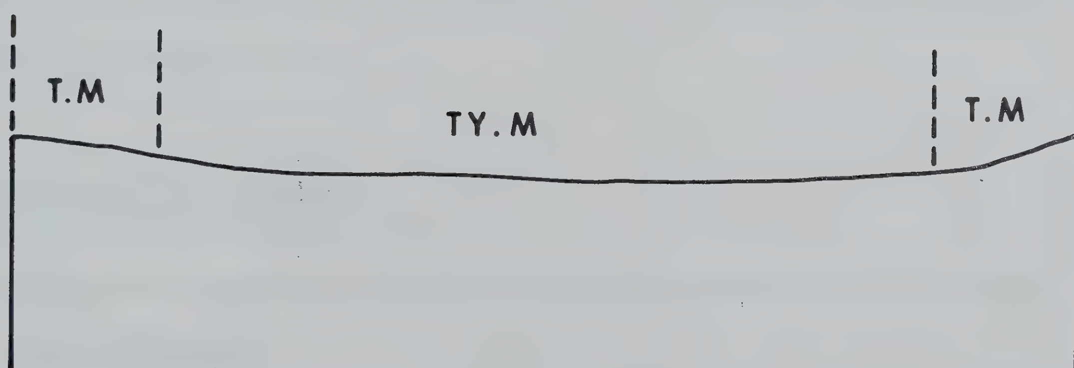


FIGURE 28: Landscape Position of Soils within Soil Unit H1

Miscellaneous Land Features

Several units have been mapped as miscellaneous land features. They are as follows:

(1) Intermittent Slough (I) -- These are sloughs that have standing water in them for a short period of time during the growing season but are sufficiently wet the remainder of the year to prevent them being utilized as cropland;

(2) Permanent Sloughs (P) -- These are sloughs where water remains for the entire growing season during a normal year; and

(3) Anthropogenic Soils (Ap) -- These units were established to recognize deep plowing sites within the study area. These plots have been established in conjunction with research on deep plowing by Alberta Agriculture.

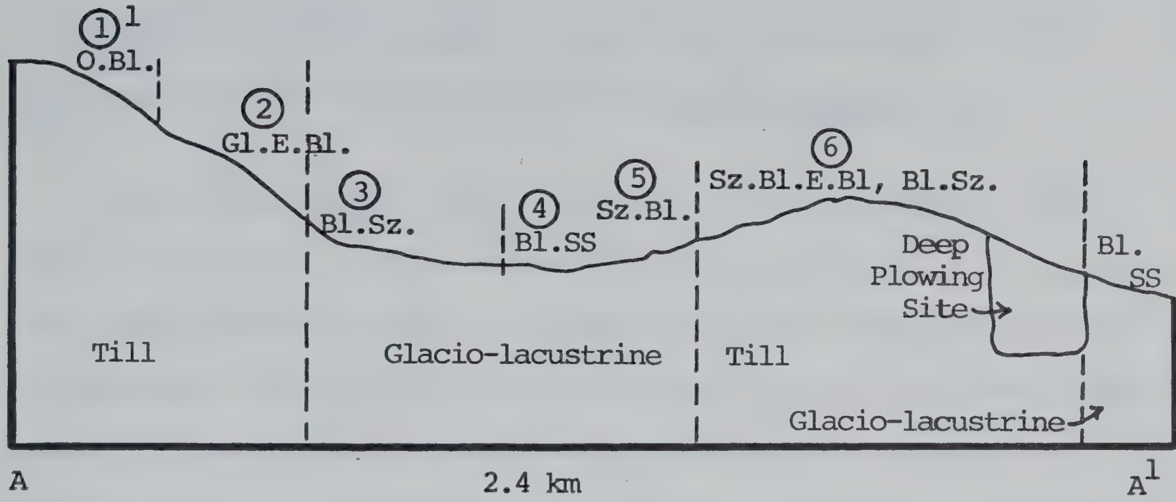
Description of Soil Transects

Three soil transects (Figure 29) were described within the study area. These included:

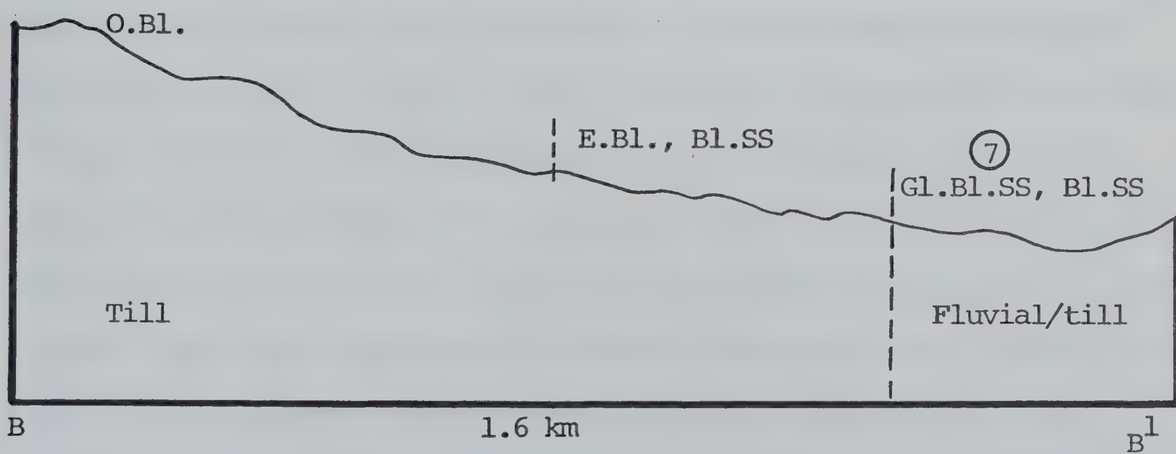
(a) Chernozemic soils developed on till, in the upper areas to Solonetzic soils developed on glacio-lacustrine materials in the lower areas $(A - A^1)$,

(b) Chernozemic soils developed on till in the upper areas, to Solonetzic and Chernozemic developed on till in the mid-slope areas to Solonetzic soils developed on fluvial/till in the lower areas $(B-B^1)$, and

(c) Chernozemic soils developed on till in the upper areas to Chernozemic and Solonetzic soils developed on glacio-lacustrine material in the mid to lower slope position to Solonetzic soils developed on



[1] Reference number for analtyical data in Appendix 2.



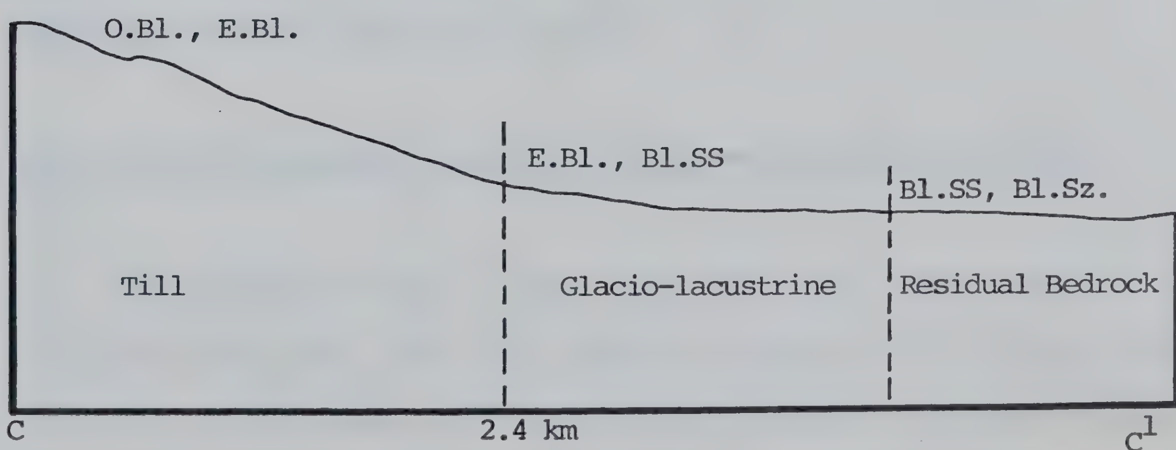


FIGURE 29: Schematic diagram of selected toposequences within the study site

residual bedrock material in the lower slope positions (C-C^1). (Analytical data for these toposequences are in Appendix 2).

The toposequences within these transects are similar to those described by Pawluk, Joffe, and Bentley and Rost (Figure 1) in that in areas where Solonetzic soils are found the zonally normal soils which in the case of the study area are Chernozemic soils, occupy the higher, better drained areas while the mid to lower areas are occupied by Solonetzic soils or gleyed versions of the zonally normal soils. Using this relationship it should be possible to assess the degree of limitation to deep plowing a soil represents by knowing where in the landscape that particular soil(s) occurs. Chemical relationships could also be used. Using the data from Appendix 2 it is shown for soils in the study area that generally as one goes downslope from areas of Chernozemic soils to areas of Solonetzic soils, chemical characteristics of the soil changes; electrical conductivity, percent saturation, sodium adsorption ratio, sodium content and soil pH all increase whereas the calcium content decreases. This information in conjunction with the assessment guidelines outlined in Table 2 should indicate the likely degree of limitation to deep plowing these areas.

Application of Assessment Guidelines for Deep Plowing to Mapped Soil Units

The guidelines (Table 2) were tested using soil units mapped within the study area. Each soil unit was assessed as to its degree of limitation for the eleven criteria outlined in Table 3. All soil units, except those of Soilscape Groups G and H which were already given a

TABLE 3 : Degree of Limitations of Soil Units within the Leduc Study Area for Deep Plowing

SOIL UNIT	SLOPE CLASSES	SLOPE LENGTH	SURFACE STONINESS	SOIL DRAINAGE	SOIL TEXTURE	THICKNESS OF C HORIZON	PARENT MATERIAL	Ca (meq/ℓ)	Ca/Na	pH	SOIL LANDSCAPES
A1	S[1]	N/S	N/S	N/S	M	S	N/S	M-S	N/S	M	N/S
A2	S	N/S	N/S	N/S	M	S	N/S	M-S	N/S	M	N/S
B1	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	M	N/S
B2	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	M	N/S
B3	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	N/S	N/S
B4	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	N/S	M	N/S
B5	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	M	N/S
B6	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	N/S	M	N/S
B7	N/S	N/S	N/S	N/S	M	M-S	M-S	M-S	N/S	M	N/S
C1	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	N/S	N/S
C2	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	N/S	N/S	N/S
D1	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	N/S	N/S	N/S
D2	N/S	N/S	N/S	N/S	M	N/S	N/S	N/S	M-S	N/S	N/S
D3	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	M-S	M	N/S
D4	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	M-S	N/S	M
D5	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	M-S	N/S	N/S
E1	N/S	N/S	N/S	N/S	M	M-S	N/S	M-S	M-S	N/S	M
E2	N/S	N/S	N/S	N/S	M	N/S	N/S	M-S	M-S	N/S	M
E3	N/S	N/S	N/S	M	M	N/S	N/S	N/S	N/S	N/S	S
F1	N/S	N/S	N/S	N/S	M	N/S	S	M-S	M-S	N/S	N/S
F2	N/S	N/S	N/S	N/S	M	N/S	S	M-S	N/S	N/S	M

[1] N/S = None to slight limitations
M = Moderate limitations
M-S = Moderate to severe limitations
S = Severe limitations

severe rating due to poor soil drainage, were given a final assessment based on that characteristic(s) that had the greatest degree of limitation to deep plowing (Table 4). In the case of unit F1, it was given a severe degree of limitation due to the type of parent material, whereas unit E1 was given a moderate to severe limitation based on three characteristics; thickness of C horizon material within the normal depth of deep plowing, the calcium content in the C horizon and the Ca/Na ratio in the surface horizon.

All the soil units tested in the study area were listed as having either a moderate to severe or severe degree of limitation with the thickness of C horizon material within plow depth and the calcium content of the C horizon being the most common limitation.

Slope length, surface stoniness, soil drainage, soil texture, soil pH and soil landscape (with the exception of unit E3) had the least limiting effect on the soil units tested. Limitations of those soil units that had Chernozemic soils as the dominant component were due primarily to physical conditions such as adverse slopes and/or insufficient thickness of C horizon material within plow depth. The Chernozemic soils generally had deeper profiles than Solonetzic soils, the exceptions being units B4 and B6 where insufficient calcium in the C horizon was the major limitation. Limitations for those soil units that had Solonetzic soils as the dominant component were due primarily to chemical conditions; the exceptions being units E3, F1 and F2 where adverse soil landscapes and parent material, respectively, were the limitations.

TABLE 4: Suitability of Soil Units in the Leduc Study Area for Deep Plowing

SOIL UNIT	DEGREE OF LIMITATION	REASON FOR LIMITATION
A1	S	Thickness of C horizon within plow depth, slope class
A2	S	Thickness of C horizon within plow depth, slope class
B1	M-S	Thickness of C horizon within plow depth, calcium content
B2	M-S	Thickness of C horizon within plow depth, calcium content
B3	M-S	Thickness of C horizon within plow depth, calcium content
B4	M-S	Calcium content
B5	M-S	Thickness of C horizon within plow depth, calcium content
B6	M-S	Calcium content
B7	M-S	Thickness of C horizon within plow depth, parent material, calcium content
C1	M-S	Thickness of C horizon within plow depth, calcium content
C2	M-S	Thickness of C horizon within plow depth, calcium content
D1	M-S	Calcium content
D2	M-S	Ca/Na ratio
D3	M-S	Calcium content, Ca/Na ratio
D4	M-S	Calcium content, Ca/Na ratio
D5	M-S	Calcium content, Ca/Na ratio
E1	M-S	Thickness of C horizon within plow depth, calcium content, Ca/Na ratio
E2	M-S	Calcium content, Ca/Na ratio
E3	S	Soil landscape
F1	S	Parent material
F2	S	Parent material
G1	S	Soil drainage
G2	S	Soil drainage
G3	S	Soil drainage
G4	S	Soil drainage
G5	S	Soil drainage
H1	S	Soil drainage

All the soil units are rated as moderate to severe or severe in their degree of limitation. This is due to the generality of the chemical criteria used, especially the calcium content of the C horizon. One must recognize that the application of the guidelines to a soil unit are not site specific due to variability within a unit.

Practical Considerations:

1. Each soil unit or group of units should be assessed individually before making a decision whether or not to deep plow as physical and chemical variability will occur within similar soil units. This is the case for soil texture. All the soil units assessed had moderate degrees of limitation. However, within individual units there could be variations in texture. This is especially true for those units (B4 and B7) that have developed on fluvial materials or have a lithological discontinuity within the profile.
2. Due to poor internal drainage the minor inclusions of the following soil units should not be deep plowed if possible: B1, B2, B5, C2, D3, D4, E2 and F2.
3. Due to imperfect internal drainage, caution should be taken when deep plowing the minor inclusions of the following soil units: B2, B3, B4, D1 and E1.
4. Due to excessively moist soil conditions associated with Soilscape Groups G and H, deep plowing should be avoided on these soils.
5. Caution should be exercised when deep plowing units F1 and F2 to avoid incorporating sodic bedrock into the soil solum.

CONCLUSION

This research project was intended as a study to develop a system for assessing soil-landscape suitability for deep plowing. This system was tested on soil units mapped within a study site near Leduc, Alberta.

Although it is the author's belief that this project was successful from the standpoint of the establishment of a set of general criteria for the assessment of soil suitability for deep plowing, there are areas where more research is needed. Possible considerations include the effect of changes in slope aspect and agro-climatic zone on soil-landscape limitations to deep plowing, the inclusion of S.A.R. values in the assessment guidelines as an indication of an active discharge or relic feature and the effect of deep plowing on non-Solonetzic soils.

For such a guideline to be effective the chemical data should also be refined. The value of 20 meq/ℓ of calcium in the C horizon may provide in itself insufficient data on the degree of limitation present without consideration being given to chemical data for the B horizon. Less than 20 meq/ℓ of calcium could be a none-to-slight limitation depending upon the chemical status of the B horizon. The question which arises is, "If a soil is tested as having 19 meq/ℓ or 21 meq/ℓ of calcium in the C horizon, what degree of limitation is present?" More data are also required on the chemical composition of the B and C horizons that will prevent resealing of the mixed subsoil after deep plowing and produce a condition conducive to good root growth.

As pointed out in the Literature Review, a technical classification

system, as outlined by Bartelli (1978), rates all the criteria in a set of guidelines as being of equal importance. For a study such as this perhaps criteria should be assigned a priority rating in regards to their importance to deep plowing. For example, the calcium content (meq/ℓ) in the C horizon could be considered as being less important to deep plowing than the thickness of the C horizon within plow depth. This approach could reduce the degree of limitation assigned to a unit such that soil units B4, B6 and D1 might have a moderate degree of limitation instead of a moderate to severe degree of limitation.

Another consideration is the scale of mapping. Using the soil unit approach to mapping, at a scale of 1:15840, there may be too much variability allowed in individual soil units for the application of guidelines of this type to be effective. Perhaps mapping at a larger scale would produce units with less variability. However the distribution of different kinds of soils in Solonetzic soil landscapes is often erratic and one kind of soil changes to another over very short laterial distances. Therefore even at larger map scales, many map units would be complexes and continue to have great variability. Finally on larger scale maps, individual fields may include a number of map units which would have to be considered together when management decisions are made.

More study is required on the hydrological effects of deep plowing. One concern is whether or not cultivation of soils in the midline position will enhance the development of a localized discharge situation or the creation of a perched water table at the depth of maximum plow penetration. This concern could prove unfounded if the fine texture associated with the subsoil of Solonetzic soils could absorb and buffer

the effects of any excess water in the profile.

Post plowing management is also an area requiring further research, especially the effects of injecting soil amendments, such as gypsum, into the subsoil as it is mixed to speed up the amelioration process.

The guidelines established in this study are a compilation of the presently available data. As more information becomes available from on-going research, these guidelines will have to be modified.

BIBLIOGRAPHY

AGRICULTURE CANADA, 1976. Glossary of Terms in Soil Science. Publ. 1459. Information Services, Ottawa.

ARSHAD, M.A. and S. PAWLUK, 1966. Characteristics of Some Solonetzic Soils in the Glacial Lake Edmonton Basin of Alberta. J. Soil Sci., 17. pp. 36-47.

BALLANTYNE, A.K., 1976. Soluble Salts. In Canada Soil Survey Committee, Manual on Soil Sampling and Methods of Analysis. McKeague, J.A., Ed. Soil Research Institute, Central Experimental Farm, Ottawa.

BARTELLI, L.J., 1978. Technical Classification System for Soil Survey Interpretation. In Advances in Agronomy, Vol. 30. Brady, N.C., Ed. Am. Soc. of Agr. pp. 247-288.

BENTLEY, C.F. and C.O. ROST, 1946. A Study of Some Solonetzic Soil Complexes in Saskatchewan. Scientific Agriculture 27:7.

BOWSER, W.E., 1967. Agro-Climatic Areas of Alberta. Alberta Soil Survey, Edmonton.

BOWSER, W.E., KJEARSGAARD, A.A., PETERS, T.W. and R.E. WELLS, 1962. Soil Survey of Edmonton Sheet. Report No. 21. Alberta Soil Survey, University of Alberta, Edmonton.

CAIRNS, R.R., 1977. Solonetzic Soils and their Management. Agriculture Canada Publ. 1391. Information Services, Ottawa.

CAIRNS, R.R., 1978. Cultural Practises for Solonetzic Soils. In Solonetzic Soils Technology and Management in Alberta. Toogood, J.A. and R.R. Cairns, co-editors. Bull. B-78-1, 2nd ed. Dept. of Extension, Univ. Alberta.

CAIRNS, R.R. and J.C. HERMANS, 1978. Deep Plowing of Solonetzic Soils. In Solonetzic Soil Technology and Management in Alberta. Toogood, J.A. and R.R. Cairns, co-editors. Bull. B-78-1, 2nd ed. Dept. of Extension, Univ. Alberta.

CANADA SOIL SURVEY COMMITTEE, 1976. Manual on Soil Sampling and Methods of Analysis. McKeague, J.A., Ed. Soil Research Institute, Central Experimental Farm, Ottawa.

CANADA SOIL SURVEY COMMITTEE, SUB-COMMITTEE ON SOIL CLASSIFICATION, 1978. The Canadian System of Soil Classification. Can. Dept. Agric. Publ. 1646. Supply and Services Canada, Ottawa. 164 pp.

CARSON, J., McCOY, D., HOGKINS, L., HERMANS, J. and S. ELIUK, 1979. Chemical Method as a Criteria in Assessing Deep Plowing of Solonetzic Soils. In Solonetzic Soils in Alberta. Alberta Solonetzic Soils Sub-Committee, A Progress Report, March 1980. Alberta Agriculture. pp. 36-47.

CEROICI, W., 1978. Hydrology of the Southwest Segment, Edmonton Area, Alberta. Earth Sciences Report 78-5. Alberta Research Council.

COEN, G.M., 1977. Soil Survey of Yoho National Park, Canada. Alberta Soil Survey Report No. 7. Alberta Institute of Pedology No. S-77-37. Land Resource Research Institute. Publ. No. 1.

CROWN, P.H., 1977. Soil Survey of Elk Island National Park. Alberta Institute of Pedology S-77-38.

DUMANSKI, J. (CHAIRMAN), 1975. The Canada Soil Information System (CanSIS) Manual for Describing Soils in the Field. Working Group on Soil Survey Data, Soil Research Institute, Central Experimental Farm, Ottawa.

ELLIS, J.G., ACTON, D.F. and H.C. MOSS, 1970. The Soils of the Rosetown Map Area, 72-0. Saskatchewan Extension Publ. 202. Extension Division, University of Saskatchewan, Saskatoon.

ENVIRONMENT CANADA, 1967. Soil Capability for Agriculture, Edmonton 83-H. Supply and Services Canada, Ottawa.

GLINKA, K.D., 1926. Reclamation of Solonets Soils in the U.S.S.R. Tyurin, I.V., Ed. 1960.

GREENLEE, G.M., 1980. Guidebook for Use with Soil Survey Reports of Alberta Provincial Parks and Recreation Areas. (Provisional) Earth Sciences Report, Alberta Institute of Pedology No. M-80-2.

HARKER, D. BROOK, WEBSTER, G.R. and R.R. CAIRNS, 1977. Factors Contributing to Crop Response on a Deep Plowed Solonetz Soil. Can. J. Soil Sci. 57. pp. 279-287.

HERMANS, J.C., 1980. Personal communication.

JENNY, H., 1941. Factors of Soil Formation. McGraw-Hill Book Company Inc. New York.

JOFFE, J.S., 1936. Pedology. Rutgers University Press.

KJEARSGAARD, A.A., 1980. Soil Survey Interpretations for Deep Plowing. In Solonetzic Soils of Alberta. Alberta Solonetzic Soils Sub-committee, A Progress Report, April 1980. Alberta Agriculture. pp. 37-43.

KURGANSKIIYS, V. and YAKOEV'S, K., 1937. Soil Science 43.

LESKIW, L.A., 1971. Relationship Between Soils and Groundwater in Field Mapping Near Vegreville, Alberta. M.Sc. Thesis. Univ. Alberta.

MACLEAN, A.H., 1974. Soil Genesis in Relation to Groundwater and Soil Moisture Regimes near Vegreville, Alberta. Ph.D. Thesis. Univ. Alberta.

MENON, G., 1971. Details of Soil Distribution in Central Strathcona County, Alberta. M.Sc. thesis. Univ. Alberta.

MOELL, C., 1977. Groundwater Monitoring at Leduc Sanitary Landfill, NE 10-52-26-W4. Interim Report, Dept. of Environment, Edmonton.

MURATOVA, V.S., 1958. Salt Accumulation Processes in the Soils and Groundwater of the Mil'sk Plain Kura-Araks Lowland. Sov. Soil Sci. 6.

ORVEDAL, A.C., 1978. Technical Classification System for Soil Survey Interpretation. <u>In</u> Advances in Agronomy. Vol. 30. Brady, N.C., Ed. Am. Soc. Agr. 250.

ORVEDAL, A.C. and M.J. EDWARDS, 1978. Technical Classification System for Soil Survey Interpretation. <u>In</u> Advances in Agronomy. Vol. 30. Brady, N.C., Ed. Am. Soc. Agr. 250.

PAWLUK, S., DUMANSKI, J. and J. TOTH, 1969. Notes from the Field Tour Held in Conjunction with the Symposium, May 14, 1969. <u>In</u> Pediology and Quaternary Research. Univ. Alberta Printing Dept., Edmonton.

PETERS, T.W., 1978. Introduction. <u>In</u> Solonetzic Soils Technology and Management in Alberta. Toogood, J.A. and R.R. Cairns, co-editors. Bull. B-78-1, 2nd ed. Dept. of Extension, Univ. Alberta.

RUSSELL, E.J., 1961. Soil Conditions and Plant Growth. 9th ed. London.

SANDOVAL, F.M., 1978. Deep Plowing Improves Sodic Claypan Soils. Reprint 919. Farm Research Vol. 35:4. pp. 15-18.

SANDOVAL, F.M., 1979. Personal communication.

SANDOVAL, F.M. and G.A. REICHMAN, 1971. Some Properties of Solonetzic (Sodic) Soils in Western North Dakota. Can. J. Soil Sci. 51:143-155.

SZABOLCS, I., 1965. Proceedings of the Symposium on Sodic Soils. Budapest. Agrokemia 14.

SZABOLCS, I., 1971. European Solonetz Soils and their Reclamation. Budapest. Akademiai Kiado.

VALENTINE, K.W. (CHAIRMAN), 1979. Mapping Systems Working Group. A Proposed Soil Mapping System for Canada. Report submitted to Canada Expert Committee on Soil Survey, Land Resource Research Institute, Agriculture Canada, Ottawa.

WESTGATE, J.A., 1969. The Quaternary Geology of the Edmonton Area, Alberta. In Pedology and Quaternary Research. Pawluk, S., Ed. Alberta Institute of Pedology.

APPENDIX 1

The following is a list of Pedon descriptions outlining the physical, chemical and landscape characteristics of the major soils within the project area. They are to be used as a central concept for the description of similar soils. Hence, there will be variability from the following described profiles regarding soil morphological characteristics.

The format that will be used for the profile descriptions is the one described on page 139 of "The Canadian System of Soil Classification," C.D.A. Publication 1646, 1978. The terminology used is that outlined in "The Canada Soil Information System - Manual for Describing Soils in the Field, 1978."

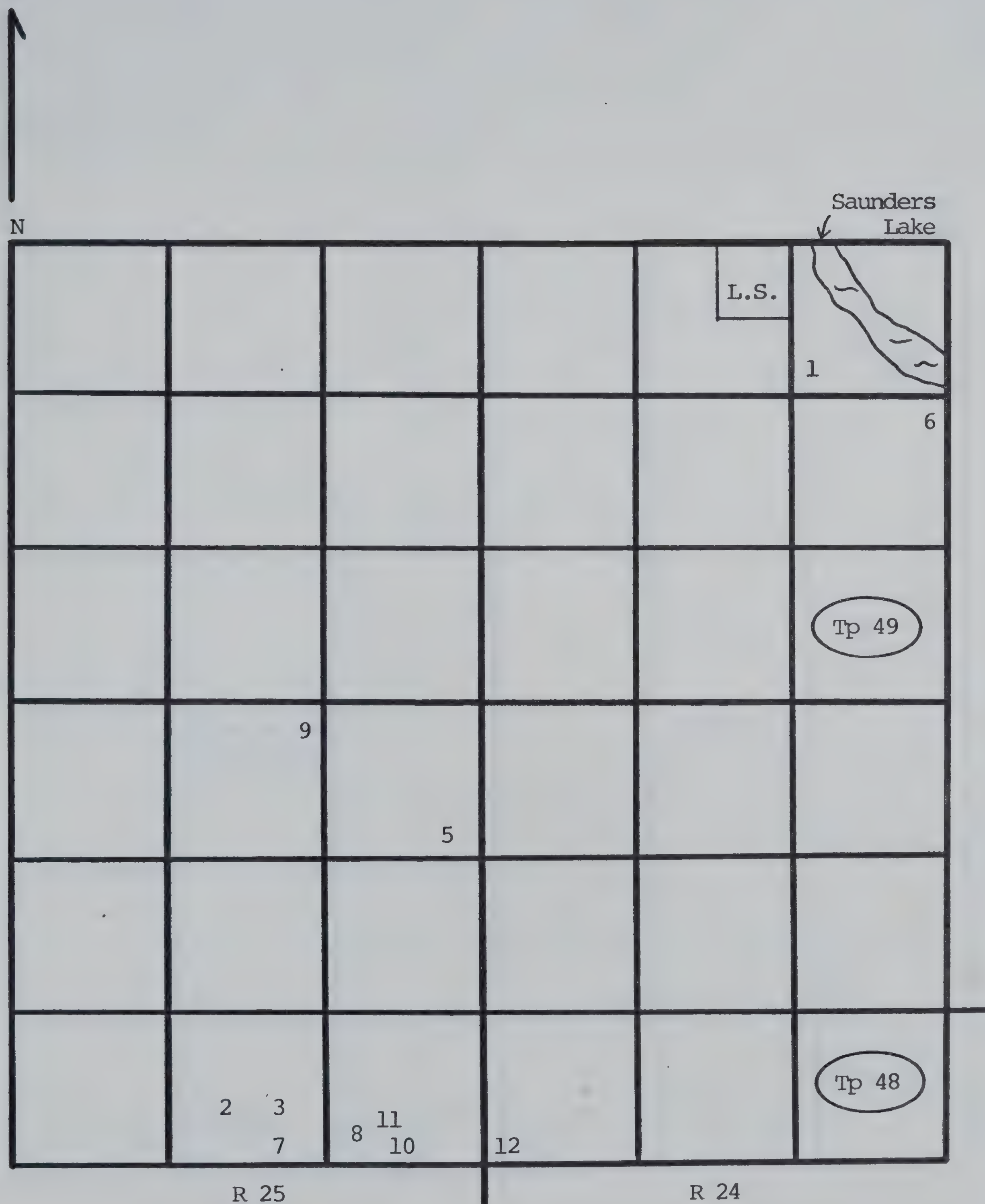


FIGURE 30: Sketch Map Showing Locations of Pedons Described

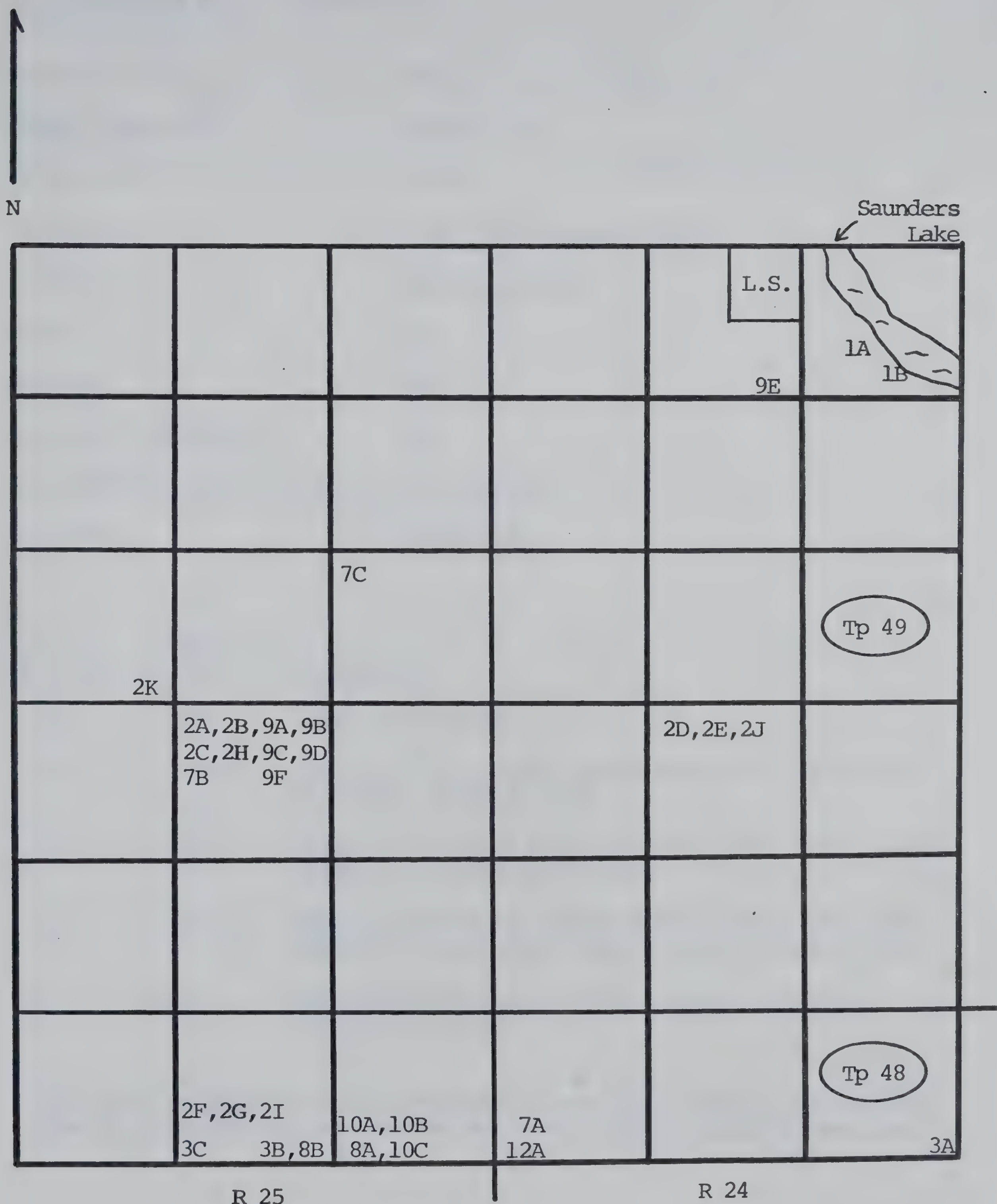


FIGURE 31: Sketch Map Showing Locations of Selected Variants to Profile Descriptions

MAP REFERENCE No. 1 (FIGURE 30)

Classification:	Orthic Dark Gray Chernozem
Parent Material:	Glacial Till
Soil Units:	A1, A2
Location:	SE 28, Twp 49, R 24, W4th
Landform:	Hummocky moraine
Slope:	11%
Aspect:	N.E.
Elevation (M.A.S.L.):	732
Estimated Internal Drainage:	Well drained
Land Use:	Annual Crop

Horizon	Depth (cm.)	Description
L-H	3-0	Loose leaf litter
Ap	0-22	Black (10 YR, 2/1 m), loam, granular, clear wavy boundary, slightly acid
Ahe	22-30	Very dark grayish brown (10 YR 3/2 m), loam, platey, clear wavy boundary, neutral
Bt	30-75	Dark grayish brown (10 YR 4/2 m), clay loam, subangular blocky, clear wavy boundary, medium acid
C	75+	Dark brown to brown (10 YR 4/3 m), clay loam, massive, neutral

- this soil is found in association with Dark Gray Luvisols which differ from it by having an Ahe horizon and an Ae horizon thicker than 5 cm.

Analytical Data for Profile Description re: Map Reference No. 1

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ap	0.2	50	0.4	1.4	0.4	6.4
Ahe	0.4	50	0.2	2.8	0.3	6.7
Bt	0.1	50	0.3	0.6	0.2	5.9
C	0.5	44	0.4	3.0	0.6	7.2

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 1

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
1A[1] -- ORTHIC DARK GRAY CHERNOZEM						
Ah	0.3	50	0.3	4.1	0.4	6.1
Ahe	0.3	43	0.5	2.9	0.6	6.4
Bt_1	0.2	50	0.5	2.5	0.6	6.5
Bt_2	0.3	49	0.7	2.1	0.8	6.7
C	0.3	50	0.8	2.0	0.9	6.5
1B -- ORTHIC DARK GRAY CHERNOZEM						
Ah	0.3	50	0.2	3.5	0.3	6.3
Ahe	0.3	43	0.5	1.2	0.4	6.6
Bt_1	0.2	38	0.3	3.7	0.4	6.3
Bt_2	0.3	44	0.4	2.3	0.5	6.2
Ck_1	0.2	40	0.4	2.2	0.5	6.4
Ck_2	0.4	46	0.5	3.9	0.7	6.0

1 - Map Reference Number (Figure 31)

MAP REFERENCE NO. 2

Classification:	Orthic Black Chernozems
Parent Material:	Glacial Till
Soil Units:	Bl, WlBl, B2, B4, WlB6, B6, B8, B9, B10, D3
Location:	2 SW 35, Twp 48, R 24, W4th
Landform:	Undulating moraine
Slope:	5%
Aspect:	E
Elevation (M.A.S.L.):	765
Estimated Internal Drainage:	Well drained
Land Use:	Annual Crop

Horizon	Depth (cm.)	Description
Ap	0-30	Very dark gray to black (10 YR 3/1-2/1 m), loam, granular, clear wavy boundary, slightly acid
Bt	30-65	Dark brown (10 YR 4/3 m), clay loam, prismatic to angular blocky, clear wavy boundary, medium acid
BCk	65-75	Yellowish brown (10 YR 5/4 m), clay loam, weak blocky, clear wavy boundary, medium acid
Ck	75+	Brown (10 YR 5/3 m), sandy clay loam, massive, mildly alkaline

- the same soil developed on glaciolacustrine material will have a similar profile description

Analytical Data for Profile Description re: Map Reference No. 2

Profile	E.C. (Saturated Paste)	% Sat'r (Saturated Paste)	S.A.R. (Saturated Paste)	Ca meq/ℓ (Saturated Paste)	Na meq/ℓ (Saturated Paste)	pH H_2O
Ap	0.2	54	0.3	2.6	0.4	5.4
Bt	0.3	50	0.6	2.6	0.7	5.5
BCk	0.3	50	0.9	1.1	0.9	6.0
Ck	0.5	49	0.6	3.1	0.9	7.4

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 2

Profile	E.C. (Saturated Paste)	% Sat'r (Saturated Paste)	S.A.R. (Saturated Paste)	Ca meq/ℓ (Saturated Paste)	Na meq/ℓ (Saturated Paste)	pH H_2O
2A -- ORTHIC BLACK CHERNOZEMS						
Ah	0.4	63	0.5	3.6	0.8	6.5
Bt	0.3	50	0.9	2.5	1.1	7.3
Cca	0.7	47	2.3	3.6	3.5	8.0
2B -- ORTHIC BLACK CHERNOZEM						
Ah	0.3	56	0.2	5.0	0.4	6.3
Bt_1	0.3	49	0.3	3.4	0.4	6.5
Bt_2	0.3	48	0.3	3.5	0.4	6.7
C	0.3	50	0.4	4.4	0.7	6.8
2C -- ORTHIC BLACK CHERNOZEM						
Ah	0.4	50	0.3	4.4	0.4	6.4
Bt_1	0.3	50	0.2	2.5	0.3	6.6
Bt_2	0.2	50	0.4	1.6	0.4	6.6
Ck	0.5	46	0.4	4.3	0.6	5.9

Profile	E.C.	% Sat'r	S.A.R.	Ca (meq/ℓ)	Na (meq/ℓ)	pH
	Saturated Paste			Saturated Paste		H_2O
2D -- ORTHIC BLACK CHERNOZEM						
Ap/Ah	0.4	67	0.9	3.8	1.4	7.2
Bt	0.4	50	1.2	3.6	1.8	8.0
BCk	0.6	56	2.4	3.0	3.4	6.9
Ccak	0.6	46	2.9	3.8	4.3	8.2
2E -- ORTHIC BLACK CHERNOZEM						
Ap/Ah	0.5	56	1.4	4.7	2.3	7.2
Btg	0.7	43	2.7	4.6	4.4	8.1
II Cca	3.4	50	2.5	34.1	11.4	7.7
2F -- ORTHIC BLACK CHERNOZEM						
Ap	0.2	50	0.5	2.0	0.6	6.4
Bt_1	0.2	57	1.0	1.1	0.9	5.6
Bt_2	0.3	50	0.7	2.4	0.9	6.2
BCk	0.5	50	0.6	6.2	1.2	6.5
Ck	0.5	52	0.8	4.9	1.3	7.4
2G -- ORTHIC BLACK CHERNOZEM						
Ap	0.2	54	0.3	2.6	0.4	5.4
Bt	0.3	50	0.6	2.6	0.7	5.5
BCk	0.3	50	0.9	1.1	0.9	6.0
Ck	0.5	49	0.6	3.1	0.9	7.4
2H -- GLEYED BLACK CHERNOZEM						
Ah	0.6	64	0.4	6.0	0.8	6.3
Btg_1	0.3	50	0.5	3.2	0.7	7.1
Btg_2	0.3	50	0.3	3.8	0.5	6.9
Ckg	1.1	50	0.6	8.3	1.4	7.5
II Ckg	0.5	50	0.8	3.4	1.2	7.7

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
2I -- GLEYED BLACK CHERNOZEM						
Ap/Ah	0.3	69	0.6	2.4	0.7	5.9
Btg	0.9	48	2.8	4.4	4.6	6.5
BCg	0.4	42	0.8	3.3	1.1	7.4
II Ccag	0.5	43	0.9	4.2	1.5	7.8
2J -- GLEYED BLACK CHERNOZEM, carbonated						
Apk	0.4	57	1.5	4.5	2.3	6.3
Btkg	0.6	50	3.1	4.0	4.7	7.7
Ckg	1.3	49	10.5	3.4	13.9	8.0
2K -- ORTHIC BLACK CHERNOZEM, carbonated						
Ap	0.5	62	1.1	2.9	1.6	
Btk	0.5	50	2.8	1.3	2.7	
BCk	0.9	50	3.6	2.9	5.1	
Ck	1.7	50	3.7	7.8	8.6	

MAP REFERENCE NO. 3

Classification:	Eluviated Black Chernozem
Parent Material:	Glacial till
Soil Units:	A1, B1, B3, B5, B6, W1B6, B7, B8, B9, B10, D1, D2, D3
Location:	SE 35, Twp 48, R 25, W4th
Landform:	Undulating moraine
Slope:	4%
Aspect:	SE
Elevation (M.A.S.L.):	762
Estimated Internal Drainage:	Well drained
Land Use:	Annual crop

Horizon	Depth (cm.)	Description
Ap	0-20	Very dark gray (10 YR 3/2 m), loam, granular, clear wavy, slightly acid
Ae	20-25	Light brownish gray to grayish brown (10 YR 6/2-5/2 m), loam, platey, abrupt wavy boundary, mildly alkaline
Bt	25-75	Yellowish brown (10 YR 5/4 m), clay loam, subangular blocky, clear wavy boundary, moderately alkaline
Cca	75+	Brown to dark brown (10 YR 4/3-3/3 m), clay loam, massive, moderately alkaline

- the same soil developed on glacio-lacustrine or residual bedrock material will have a similar profile description

- in some instances (B5, W1B6, B10) a thin fluvial veneer may overlie the glacial till

Analytical Data for Profile Description re: Map Reference No. 3

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ap	0.4	65	1.3	2.7	1.7	6.3
Ae	0.5	47	3.1	4.0	4.7	7.4
Bt	0.7	59	6.2	1.5	6.2	8.1
Cca	1.2	73	9.3	2.5	11.4	8.2

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 3

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
3A -- ELUVIATED BLACK CHERNOZEM						
Ap	0.2	58	0.2	1.7	0.2	6.3
Ae	0.3	50	0.2	2.0	0.2	6.8
Bt_1	0.2	50	0.2	1.7	0.2	7.0
Bt_2	0.1	50	0.4	0.8	0.3	6.7
C	0.6	50	0.3	3.2	0.5	5.3
3B -- ELUVIATED BLACK CHERNOZEM						
Ap	0.4	65	1.3	2.7	1.7	6.3
Ae	0.5	47	3.1	4.0	4.7	7.4
Bt	0.7	59	6.2	1.5	6.2	8.1
Cca	1.2	73	9.3	2.5	11.4	8.2
3C -- GLEYED ELUVIATED BLACK CHERNOZEM						
Ap	0.4	74	0.4	4.3	0.7	5.9
Ae	0.3	45	0.4	4.2	0.6	6.5
Btg_1	0.3	48	0.5	3.8	0.7	6.4
Btg_2	0.3	50	1.3	0.4	0.9	6.8
II Ckg	0.7	46	1.0	4.9	1.7	7.4

MAP REFERENCE NO. 4

Classification:	Orthic Humic Gleysol
Parent Material:	Glacio-lacustrine
Soil Units:	B5, G3, G4
Location:	NW 31, Twp 48, R 24, W4th
Landform:	Depressional areas - slough
Slope:	
Aspect:	Level
Elevation (M.A.S.L.):	767
Estimated Internal Drainage:	Poorly drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
LFH	5-0	Loose leaf litter in various stages of decomposition
Ah	0-10	Very dark gray to black (10 YR 3/1-2/1 m), loam to silty clay loam, granular, clear wavy boundary, slightly acid
Bgk	10-30	Grayish brown to dark grayish brown (10 YR 5/2-4/2 m), loam to clay loam, subangular, blocky, abrupt wavy boundary, neutral
Cgca	30+	Dark gray to very dark gray (7.5 YR 4/0-3/0 m), clay loam, massive, mildly alkaline

- other Orthic Humic Gleysols may show some saline tendancies if they happen to develop in an area of Solonetzic soils
- the same soil developed on colluvial or fluvial material will have a similar profile description

Analytical Data for Profile Description re: Map Reference No. 4

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ah	0.9	70	6.3	1.6	6.9	6.3
Bgk	1.3	65	7.3	2.5	10.2	7.1
Cgca	5.5	65	9.0	23.1	36.2	7.7

MAP REFERENCE NO. 5

Classification:	Rego Humic Gleysol
Parent Material:	Glacio-lacustrine
Soil Units:	C2, G3, G4
Location:	SE 12, Twp 49, R 25, W4th
Slope:	
Aspect:	S
Elevation (M.A.S.F.):	751
Estimated Internal Drainage:	Poorly drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
LFH	5-0	Loose leaf little in various stages of decomposition
Ahg_1	0-15	Black (10 YR 2/1 m), loam to silty loam, granular, clear wavy boundary, slightly acid
Ahg_2	15-45	Very dark gray (10 YR 3/1 m), silty clay loam, granular to subangular blocky, abrupt wavy boundary, neutral
Cg	45+	Dark gray to very dark gray (7.5 YR 4/0-3/0 m), clay loam, massive, neutral

- the same soil developed on fluvial or colluvial material will have a similar profile description

Analytical Data for Profile Description re: Map Reference No. 5

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ahg_1	0.3	59	0.2	2.2	0.2	5.9
Ahg_2	0.2	72	0.2	2.0	0.2	6.4
Cg	0.2	50	1.5	1.5	0.2	6.5

MAP REFERENCE NO. 6

Classification:	Humic Luvic Gleysol
Parent Material:	Fluvial
Soil Units:	G2
Location:	NE 21, Twp 49, R 24, W4th
Landform:	Fluvial
Slope:	.5%
Aspect:	NW
Elevation (M.A.S.L.):	724
Estimated Internal Drainage:	Poorly drained
Land Use:	Native Pasture

Horizon	Depth (cm.)	Description
LFH	5-0	Loose leaf litter in various stages of decomposition
Ah	0-10	Black (10 YR 2/1 m), loam, granular, clear wavy boundary, medium acid
Aeg	10-18	Gray to dark gray (10 YR 5/1-4/1 m), loam to fine sandy loam, platey, clear wavy boundary, medium acid
Btg	18-65	Brown to dark brown (10 YR 4/3 m), clay loam, subangular blocky, clear wavy boundary, medium acid
Ckg	65+	Brown to grayish brown (10 YR 5/3-5/2 m), clay loam, massive, neutral

MAP REFERENCE NO. 7

Classification:	Black Solodized Solonetz
Parent Material:	Glacial till
Soil Units:	B9, D3, D4, D6
Location:	SE 35, Twp 48, R 25, W4th
Landform:	Inclined moraine
Slope:	2%
Aspect:	SE
Elevation (M.A.S.L.):	762
Estimated Internal Drainage:	Moderately well to imperfectly
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
Ah	0-10	Very dark brown to black (10 YR 2/2-2/1 m), loam, granular, abrupt wavy boundary, medium acid
Ae	10-15	Grayish brown (10 YR 5/2 m), loam to clay loam, platey, abrupt wavy boundary, neutral
Bnt_1	15-30	Dark yellowish brown to dark brown (10 YR 4/4-4/3 m), sandy clay loam, columnar, abrupt wavy boundary, very strongly acid
Bnt_2	30-45	Dark brown to brown (10 YR 4/3 m), sandy clay loam, preomatic, clear wavy boundary, moderately alkaline
Csk	45+	Dark grayish brown (10 YR 4/2 m), sandy clay loam, massive, moderately alkaline

- the same soil developed on lacustrine material has a similar profile description

Analytical Data for Profile Description re: Map Reference No. 7

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ah	2.7	61	18.2	3.5	28.8	7.4
Ae	not sampled					
Bnt_1	0.2	42	0.5	2.6	0.6	5.7
Bnt_2	3.2	76	24.9	2.6	33.0	7.9
Csk	3.5	100	22.8	3.6	34.2	8.3

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 7

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
7A -- BLACK SOLODIZED SOLONETZ						
Ah	0.6	108	8.2	0.7	0.3	5.3
Ae	0.9	67	11.0	0.9	0.5	5.5
Bnt	1.7	69	14.1	1.3	0.7	6.1
BCk	1.9	90	17.1	1.1	0.8	7.1
Csaca	6.8	136	13.9	17.3	11.6	7.8
7B -- GLEYED BLACK SOLODIZED SOLONETZ, carbonated						
Ah	0.8	74	9.0	0.9	7.8	6.4
Ae	1.0	38	8.6	2.5	10.5	6.9
Bntjgk	2.5	64	18.8	2.7	24.9	7.8
Csk	2.8	70	17.6	4.3	27.9	8.1
7C -- GLEYED BLACK SOLODIZED SOLONETZ						
Ah	1.0	41	9.0	1.1	8.8	5.7
Ae	1.1	62	12.0	1.1	11.1	6.5
Bntg	1.2	65	10.7	1.3	10.4	7.1
BCg	2.5	94	22.1	1.2	23.2	7.8
Ckg	2.9	100	25.9	1.1	28.7	8.2

MAP REFERENCE NO. 8

Classification:	Black Solodized Solonetz
Parent Material:	Residual bedrock
Soil Units:	F1, F3
Location:	SW 36, Twp 48, R 25, W4th
Landform:	Sapiolitic
Slope:	2%
Aspect:	SE
Elevation (M.A.S.L.):	756
Estimated Internal Drainage:	Moderately well drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
Ah	0-5	Very dark brown to black (10 YR 2/2-2/1 m), loam, granular, abrupt wavy boundary, medium acid
Ae	5-10	Light brownish gray to brownish gray (10 YR 6/2-5/2 m), loam to silt loam, platey, abrupt wavy boundary, medium acid
Bnt	10-25	Dark brown (10 YR 4/3 m), clay loam, columnar, clear wavy boundary, neutral
Csk	25+	Brown (10 YR 5/3 m), clay loam, massive, strongly alkaline

- small fragments of weathered bedrock appear in the Bnt and Csk horizons

Analytical Data for Profile Description re: Map Reference No. 8

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ah	0.2	100	3.5	0.5	1.9	5.7
Ae	0.7	50	8.3	1.0	6.7	5.9
Bnt	1.0	72	9.0	2.2	10.8	6.6
Csk	1.5	62	16.8	1.2	15.0	9.0

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 8

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
8A -- BLACK SOLODIZED SOLONETZ						
Ah	0.2	100	3.5	0.5	1.9	5.7
Ae	0.7	50	8.3	1.0	6.7	5.9
Bnt	1.0	72	9.0	2.2	10.8	6.6
Csk	1.5	62	16.8	1.2	15.0	9.0
8B -- GLEYED BLACK SOLODIZED SOLONETZ, carbonated						
Ap/Ae	2.0	67	12.4	4.4	20.5	7.2
Bntgk	2.7	85	21.9	2.6	29.0	7.8
Cskg	2.5	188	21.7	1.9	24.3	8.5

MAP REFERENCE NO. 9

Classification:	Black Solonetz
Parent Material:	Glacial till
Soil Units:	B4, B9, D2, D5, D6
Location:	NE 11, Twp 49, R 25, W4th
Landform:	
Slope:	4%
Aspect:	E
Elevation (M.A.S.L.):	742
Estimated Internal Drainage:	Well to moderately well drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
Ah	0-15	Very dark gray to black (10 YR 3/1-2/1 m), loam to silt loam, granular, abrupt wavy boundary, medium acid
Bnt	15-35	Brown to dark brown (10 YR 4/3-3/3 m), clay loam, columnar, clear wavy boundary, mildly alkaline
Csk	35+	Grayish brown (10 YR 5/2 m), clay loam, massive, moderately alkaline

- the same soil developed on glacio-lacustrine material will have a similar profile description

Analytical Data for Profile Description re: Map Reference No. 9

Profile	E.C. (Saturated Paste)	% Sat'r (Saturated Paste)	S.A.R. (Saturated Paste)	Ca meq/ℓ (Saturated Paste)	Na meq/ℓ (Saturated Paste)	pH H_2O
Ah	0.3	65	1.6	4.1	2.4	5.9
Bnt	2.0	65	10.4	6.4	20.1	7.6
Csk	1.6	81	11.2	3.1	15.9	8.3

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 9

Profile	E.C. (Saturated Paste)	% Sat'r (Saturated Paste)	S.A.R. (Saturated Paste)	Ca meq/ℓ (Saturated Paste)	Na meq/ℓ (Saturated Paste)	pH H_2O
9A -- BLACK SOLONETZ						
Ah	0.5	63	0.6	5.6	1.1	6.5
Bntj	0.4	44	1.6	3.9	2.4	7.5
Csk	0.8	48	3.2	6.3	5.9	7.8
9B -- BLACK SOLONETZ						
Apg	0.2	50	0.4	2.0	0.4	6.3
Bnt	2.3	57	8.9	7.6	19.4	7.5
BC	0.2	47	0.5	1.5	0.5	6.2
Ck	0.8	66	0.3	6.1	0.6	7.0
9C -- BLACK SOLONETZ						
Ah	0.3	65	1.6	4.2	2.4	5.9
Bnt	2.0	65	10.4	6.4	20.1	7.6
Csk	1.6	81	11.2	3.1	15.9	8.3
9D -- BLACK SOLONETZ						
Ah	0.5	62	4.2	2.5	5.1	6.0
Bnt	1.0	57	6.0	4.8	9.9	6.9
Csk	1.7	65	10.1	3.7	15.9	8.2

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
9E — GLEYED BLACK SOLONETZ, saline						
Ah	0.8	94	5.6	1.6	6.1	6.0
Bntg	0.9	150	7.9	1.1	7.1	6.6
Ckg	1.7	--	11.0	2.1	14.1	7.5
Csacag	5.9	66	9.3	23.1	38.8	7.4
9F — GLEYED BLACK SOLONETZ, carbonated						
Ah	1.1	75	7.7	3.2	10.9	6.5
Bntjgk	2.6	50	17.8	3.1	25.2	7.9
Csk	4.6	75	21.4	7.1	45.4	8.0

MAP REFERENCE NO. 10

Classification:	Black Solonetz
Parent Material:	Residual bedrock
Soil Units:	F1, F3
Location:	SW 36, Twp 48, R 25, W4th
Landform:	Saprolitic
Slope:	2%
Aspect:	SE
Elevation (M.A.S.L.):	756
Estimated Internal Drainage:	Well to moderately well drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
Ap	0-15	Very dark gray to black (10 YR 3/1-2/1 m), loam, granular, clear wavy boundary, medium acid
Bnt	15-40	Brown to dark brown (10 YR 5/3-4/3 m), clay loam, columnar, clear wavy boundary, neutral
BCsak	40-50	Very dark grayish brown (10 YR 3/2 m), clay loam, prismatic, clear wavy boundary, mildly alkaline
Csak	50+	Grayish brown to dark grayish brown (10 YR 5/2-4/2 m), clay loam, massive, moderately alkaline

- weathered bedrock of the Edmonton formation appears in the BCsak and Csak horizons

Analytical Data for Profile Description re: Map Reference No. 10

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ap	1.35	88	15.2	0.8	11.8	5.8
Bnt	2.32	85	20.0	1.4	21.0	7.3
BCsak	5.0	150	19.1	6.7	45.3	7.5
Csak	5.3	150	16.6	10.7	47.3	7.9

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 10

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
10A -- BLACK SOLONETZ, saline						
Ap	1.4	88	15.2	0.8	11.8	5.8
Bnt	2.3	85	20.0	1.4	21.0	7.3
BCsak	5.0	150	19.1	6.7	45.3	7.5
Csak	5.3	150	16.6	10.7	47.3	7.9
10B -- BLACK SOLONETZ, saline						
Ah	0.8	72	10.6	0.9	7.9	6.2
Bnt	2.5	108	21.9	1.6	24.0	8.2
Csaca	6.5	200	14.2	19.8	52.4	7.9
10C -- BLACK SOLONETZ, saline						
Ah	0.9	70	6.3	1.6	6.9	6.3
Bnk	1.3	65	7.3	2.5	10.2	7.1
Cgca	5.5	90	23.1	23.1	36.2	7.7

MAP REFERENCE NO. 11

Classification:	Black Solod
Parent Material:	Glacial till
Soil Units:	D1, D3, D5
Location:	SW 36, Twp 48, R 25, W4th
Landform:	Undulating moraine
Slope:	2%
Aspect:	SE
Elevation (M.A.S.L.):	756
Estimated Internal Drainage:	Well to moderately well drained
Land Use:	Annual Crop

Horizon	Depth (cm.)	Description
Ah	0-10	Dark grayish brown to very dark grayish brown (10 YR 4/2-3/2 m), loam to silt loam, granular, clear wavy boundary, medium acid
Ae	10-13	Light brownish gray (10 YR 6/2 m), silt loam to fine sandy loam, platey, clear wavy boundary, medium acid
AB	13-18	Brown (10 YR 4/3 m), clay loam, angular blocky, clear wavy boundary, slight acid
Bnt	18-28	Yellowish brown (10 YR 5/4 m), clay loam, columnar, clear wavy boundary, moderately alkaline
Csaca	28+	Dark grayish brown (10 YR 4/2 m), clay loam, massive, moderately alkaline

- the same soil developed on glacio-lacustrine will have a similar profile description

Analytical Data for Profile Description re: Map Reference No. 11

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ah	0.8	72	10.6	0.9	7.9	6.2
Ae	not sampled					
AB	not sampled					
Bnt	2.5	108	21.9	1.6	24.0	8.2
Csaca	6.5	200	14.2	19.8	52.4	7.9

MAP REFERENCE NO. 12

Classification:	Black Solod
Parent Material:	Residual bedrock
Soil Units:	F2
Location:	SW 31, Twp 48, R 24, W4th
Landform:	Undulating moraine
Slope:	2%
Aspect:	SE
Elevation (M.A.S.L.):	762
Estimated Internal Drainage:	Well to moderately well drained
Land Use:	Native pasture

Horizon	Depth (cm.)	Description
Ah	0-5	Dark grayish brown (10 YR 4/2 m), loam, granular, clear wavy boundary, neutral
Ae	5-7	Grayish brown (10 YR 5/2 m), silt loam, platey, abrupt wavy boundary, medium acid
AB	7-15	Brown (10 YR 4/3 m), clay loam, angular blocky, clear wavy boundary, neutral
Bnt	15-45	Yellowish brown to dark yellowish brown (10 YR 5/4-4/4 m), clay loam, columnar, clear wavy boundary, mildly alkaline
Csaca	45+	Dark grayish brown (10 YR 4/2 m), clay loam, massive, mildly alkaline

- small fragments of weathered bedrock of the Edmonton Formation appear throughout the Bnt and Csaca horizon of this soil

Analytical Data for Profile Description re: Map Reference No. 12

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
Ah	0.3	90	4.3	0.7	2.9	6.6
Ae	not sampled					
AB	2.0	69	18.1	1.4	19.0	6.6
Bnt	2.4	89	19.1	1.7	23.0	7.4
Csaca	7.3	150	15.6	19.3	60.8	7.8

Analytical Data for Selected Variants for Profile Description re: Map Reference No. 12

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
12A -- BLACK SOLOD, saline						
Ah	0.3	90	4.3	0.7	2.9	6.6
AB	2.0	69	18.1	1.4	19.0	6.6
Bnt	2.38	89	19.1	1.7	23.0	7.4
Csaca	7.30	150	15.6	19.3	60.8	7.8

APPENDIX 2

The following are the analytical data for selected soils from the toposequences outlined in Figure 29.

Analytical data for selected soils from toposequences described in Figure 29.

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
1 -- ORTHIC BLACK CHERNOZEM (O.BL.)						
Ap	0.2	50	0.5	2.0	0.6	6.4
Bt_1	0.2	57	1.0	1.1	0.9	5.6
Bt_2	0.3	50	0.7	2.4	0.9	6.2
BCk	0.5	50	0.6	6.2	1.2	6.5
Ck	0.5	52	0.8	4.9	1.3	7.4
2 -- GLEYED ELUVIATED BLACK CHERNOZEM (GL.E.BL.)						
Ap	0.4	65	1.3	2.7	1.7	6.3
Aeg	0.5	47	3.1	4.0	4.7	7.4
Btg	0.7	59	6.2	1.5	6.2	8.1
Ccag	1.2	73	9.3	2.5	11.4	8.2
3 -- BLACK SOLONETZ (BL.SZ.)						
Ap/Ah	0.7	56	6.0	2.4	6.0	7.1
Bnt	0.7	56	6.1	1.1	5.3	7.3
Cca	0.8	66	7.3	1.6	7.3	8.4
4 -- BLACK SOLODIZED SOLONETZ (BL.SS)						
Ap/Ah	2.3	63	15.3	3.4	23.0	7.3
Bnt	2.8	87	21.7	3.2	30.7	7.8
Csk	2.6	150	23.7	1.9	26.5	7.3
5 -- SOLONETZIC BLACK CHERNOZEM (SZ.BL.)						
Ah	1.8	100	18.0	1.2	17.1	8.5
Bnjtj	2.3	115	26.5	0.8	21.4	9.0
Ck	3.1	100	33.3	0.9	29.8	9.2

Profile	E.C.	% Sat'r	S.A.R.	Ca	Na	pH
	Saturated Paste			meq/ℓ Saturated Paste		H_2O
6 — ELUVIATED BLACK (E.BL.)						
Ah	0.2	50	0.4	1.4	0.4	6.4
Ae	0.4	50	0.2	2.8	0.3	6.7
Bt	0.1	50	0.3	0.6	0.2	5.9
C	0.5	44	0.4	3.0	0.6	7.2
7 — GLEYED BLACK SOLODIZED SOLONETZ (GL.BL.SS)						
Ah	0.8	73	9.1	0.9	7.8	6.4
Ae	1.0	39	8.5	2.4	10.5	6.9
Bntjg	2.5	61	18.6	2.8	23.9	7.8
Cskg	2.8	68	17.3	4.2	27.5	8.1

APPENDIX 3

The following are the analytical data for selected soils from the deep plowing plots established by Alberta Agriculture described in Figure 32.

MAP REFERENCE NO.	LEGAL LOCATION
1, 2, 3	NE 12, Twp 49, R 25, W4th
4, 5	NW 13, Twp 49, R 25, W4th
6, 7, 8	NE 11, Two 49, R 25, W4th

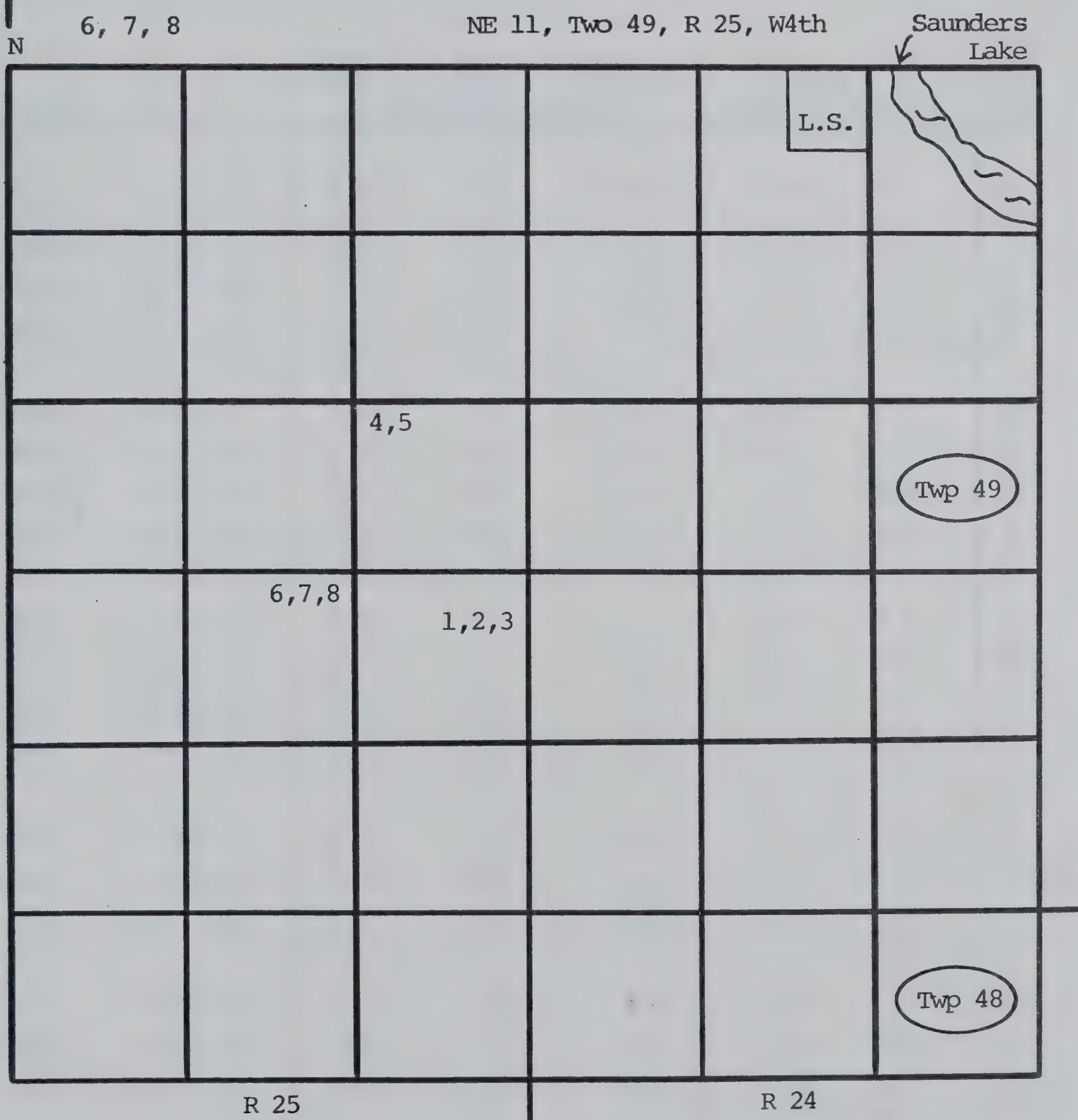


FIGURE 32: Location of Sampling Areas for Deep Plowing Sites

Analytical data for selected soils from the deep plowing plots described in Figure 32).

Profile		E.C.	% Sat'r	S.A.R.	Ca	Na	pH
		Saturated Paste			meq/ℓ Saturated Paste		H_2O
1[1]							
$Apkg_1$	0-15 cm.	1.1	62	11.0	1.1	10.0	8.0
$Apkg_2$	15-30 cm.	5.3	64	21.6	5.5	51.2	7.8
$Apkg_3$	30-45 cm.	7.2	87	21.6	7.8	66.8	7.8
Ckg	45+ cm.	3.0	100	23.8	1.2	26.6	8.7
2							
Apkg	0-15 cm.	1.8	100	18.0	1.2	17.1	8.5
$Btkg_1$	15-30 cm.	2.3	115	26.5	0.8	21.4	9.0
$Btkg_2$	30-45 cm.	3.0	130	34.2	0.8	28.6	9.1
Ckg	45+ cm.	3.1	100	33.3	0.9	29.8	9.2
3							
ABp	0-30 cm.	0.5	62	1.1	2.9	1.6	7.1
Btk	30-66 cm.	0.5	50	2.8	1.3	2.7	8.0
BCk	66-76 cm.	0.9	50	3.6	2.9	5.1	7.8
Ck	76+ cm.	1.7	50	3.7	7.8	8.6	7.8
4							
Ap	0-15 cm.	1.2	50	10.9	1.3	10.3	6.6
Apk	15-30 cm.	1.2	76	11.2	1.3	10.9	7.8
Cca	30+ cm.	1.0	50	12.1	0.9	9.4	8.7
5							
Ap	0-11 cm.	0.2	75	2.9	0.5	1.7	5.6
Apk	11-45 cm.	0.9	51	3.9	3.0	5.9	6.6
Cca	45+ cm.	0.7	50	4.0	1.8	4.5	7.6
6							
Apk	0-12 cm.	0.2	50	0.4	2.0	0.4	6.3
Bt_1	12-25 cm.	2.3	57	8.9	7.6	19.4	7.5
Bt_2	25-45 cm.	0.2	47	0.5	1.5	0.5	6.2
Ck	45+ cm.	0.8	66	0.3	6.1	0.6	7.0

Profile		E.C.	% Sat'r	S.A.R.	Ca (meq/ℓ)	Na (meq/ℓ)	pH
		Saturated Paste			Saturated Paste		H_2O
7							
$Apkg_1$	0-15 cm.	1.0	56	6.6	3.0	8.8	7.1
$Apkg_2$	15-35 cm.	1.1	83	7.8	2.9	10.3	6.8
Csaca	35+ cm.	3.8	100	15.6	6.6	35.8	8.2
8							
$Apkg_1$	0-20 cm.	0.7	50	4.2	4.4	6.0	7.6
$Apkg_2$	20-43 cm.	0.7	52	2.4	5.4	4.4	7.3
Cksag	43+ cm.	0.6	52	4.1	2.2	4.6	6.3

[1] Reference Number (Figure 32)

APPENDIX 4

The following are the analytical data used to characterize the potential limitations to deep plowing of mapped soil units within the study site.

APPENDIX 4 : Criteria for the Potential Limitations to Deep Plowing of Soil Units within the Study Site

SOIL UNIT	SLOPE CLASS	SLOPE LENGTH (m)	SURFACE STONINESS	SOIL DRAINAGE	TEXTURE	THICKNESS OF C HORIZON WITHIN USUAL PLOW DEPTH (cm)	PARENT MATERIAL	Ca (meq/ℓ)	Ca/Na	pH (H_2O)
A1	5	12+	0-1	well	CL	0	Till	8.1	6.0	6.3
A2	5	12+	0-1	well	CL	0	Till	8.7	6.5	6.3
B1	2-3	12+	0-1	well	CL	10	Till	4.5	7.1	6.3
B2	2-3	12+	0-1	well	CL	5	Till	6.1	5.6	6.4
B3	2-3	12+	0-1	well	CL	5	Till	4.1	4.4	5.9
B4	2-3	12+	0-1	rapidly-well	SiL-CL	20	Fluvial/Till	5.3	6.7	6.4
B5	2-3	12+	0-1	well	CL	5	Till	5.1	8.5	6.4
B6	2-3	12+	0-1	well	CL	15	Till	5.4	6.1	6.3
B7	2-3	12+	0-1	well to moder-ately well	SiCL-CL	5	Till/Residual	6.5	5.6	6.4
C1	1-2	12+	0-1	well to moder-ately well	SiCL-CL	5	Glacio-lacustrine	4.1	4.5	6.0
C2	1-2	12+	0-1	well to moder-ately well	SiCL-CL	5	Glacio-lacustrine	6.0	9.0	6.5
D1	2-3	12+	0-1	moder-ately well	CL	20	Till	12.8	4.5	6.6
D2	2-3	12+	0-1	moder-ately well	CL	35	Till	21.4	0.3	6.0
D3	2-3	12+	0-1	moder-ately well	CL	30	Till	5.6	0.9	6.2
D4	2-3	12+	0-1	moder-ately well	CL	35	Till	15.0	0.5	6.0
D5	2-3	12+	0-1	moder-ately well	CL	35	Till	7.0	0.4	6.1
E1	1-2	12+	0-1	well to moder-ately well	SiCL-CL	5	Glacio-lacustrine	7.0	2.0	6.2
E2	1-2	12+	0-1	well to moder-ately well	SiCL-CL	35	Glacio-lacustrine	17.0	0.4	6.1
E3	1-2	12+	0-1	Imper-fectly	SiCL-CL	30	Glacio-lacustrine	23.0	8.0	6.1
F1	1-2	12+	0-1	moder-ately well	SiCL-CL	40	Residual	16.7	0.4	6.1
F2	1-2	12+	0-1	moder-ately well	SiCL-CL	40	Residual	13.1	5.1	6.1